AN ECOLOGICAL STUDY OF THE IXODID TICK *RHIPICEPHALUS GLABROSCUTATUM* (DU TOIT, 1941)

by

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A thesis presented to Rhodes University for the degree of MASTER OF SCIENCE

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SUMMARY

An intensive study was conducted on the free-living larvae and parasitic life stages of R.glabroscutatum on Angora and Boer goats in the Uitenhage district. Free-living larvae exhibited periods of maximum relative abundance during months of generally lower rainfall, from the end of autumn to the beginning of spring. Relative larval abundance in open and gully sites was low while larvae were rarely found in bush sites. Relative abundance was higher at 20h00 than at 08h00 and 14h00. Repeated sampling in the same areas did not reduce larval numbers.

Over 99% of parasitic ticks removed from Angora and Boer goats were located on the feet. The annual occurrence of a low and variable number of parasitic immatures was synchronous with the occurrence of free-living larvae. High, less variable numbers of adult ticks were removed from goat feet from September to December, the highest numbers being recorded during October and November. The occurrence of a single period of parasitic adult abundance annually indicated a life cycle with 1 generation per anum. There were higher numbers of adult ticks on the feet of the Angora goats than on the Boer goats. Adult numbers were higher on the hind feet of both breeds of goats than on the front feet.

R.glabroscutatum adults seem to be implicated in the aetiology of foot abscesses since more infections were observed in Angora goats than in Boer goats and on the hind feet rather than the front feet within both goat groups.

In addition R.glabroscutatum adults attached at interdigital sites where abscesses also originated and reached highest numbers in October and November when abscesses were most frequently observed.

A review of distribution and host records indicated that R.glabroscutatum was limited in its distribution to the eastern Cape Province, being primarily located in South Africa's major mohair producing areas. R.glabroscutatum was classed an obligative xerophile on the basis of its recorded occurrence in non coastal areas with a low annual rainfall and Karoo and Karroid Bush vegetation. Host records for R.glabroscutatum included 10 species of wild ungulate, sheep, goats and cattle. The common site of occurrence on small stock and on small to medium sized wild animals appeared to be the legs and feet.

1. INTRODUCTION

Theiler (1962) observed that Rhipicephalus glabroscutatum (Du Toit, 1941) was found in localised areas of the eastern Cape Province being 'essentially a parasite of smaller stock' and that 'its habit of attaching to the feet between the claws often leads to extreme and painfull lameness in sheep and goats'.

Baker, cited by Hoogstraal (1978) stated that 'R.glabroscutatum has changed in recent years from a "rare species" to a common pest of South African domestic animals'. However, Rechav & Knight (1981) suggested that R.glabroscutatum has failed to modify its feeding to domestic animals.

It is probable that the limited distribution of this tick, its small size and the lack of fundamental ecological information, especially of the immature life stages, has contributed towards this controversy.

An area north of Uitenhage was selected for intensive ecological work on free-living larval life stages and life stages parasitic on Angora and Boer goats. It was anticipated that results from this important mohair producing area could be related to records of distribution and host preference of R.glabroscutatum in South Africa. The fundamental objective of the study was to produce ecological knowledge that would enable a re-evaluation of the pest status of this tick species. It was hoped that such knowledge could be incorporated in tick control programmes in the eastern Cape Province.

2. THE STUDY SITE: KUDU CAMP

2.1 A GENERAL DESCRIPTION

The farm "Brakhill" (33°33'S; 25°25'E), is situated 25km north of Uitenhage on the Graaf Reinet road (Map 1) and comprises ± 4000ha. It is divided into 25 large (± 100ha) and 45 small (± 30ha) stock camps. The area is hilly with an altitude range of 200 to 400m.

Kudu camp with an area of 355ha (Map 1), representing ± 9% of the total farm area, was selected for the study because annual mortality in Angora and Boer goats in this camp had reached 15% (Dorfling in comm.). Kudu camp consists of 8 stock camps of which 3 are large and 5 small (Map 1). The lowest point in the camp is 227m. From this point the ground rises steeply to 340m in the west, the highest point in the camp, and to 277m in the east. The low ground is a catchment area for the reservoir lying at the northern end of the camp (Map 1 and 2).

Recording sites and 'drag' sites (Key, Map 1 and Map 2) are described in Sections 3 and 4 respectively. Information concerning farm management and farm stock and experimental stock is given in Section 5.

2.2 VEGETATION*

The vegetation over most of the farm area including the study plots, is typical Fish River Scrub, characterised by the dominance of Portulacaria afra (spekboom, elephant bush) and the presence of Grewia robusta, Crassula

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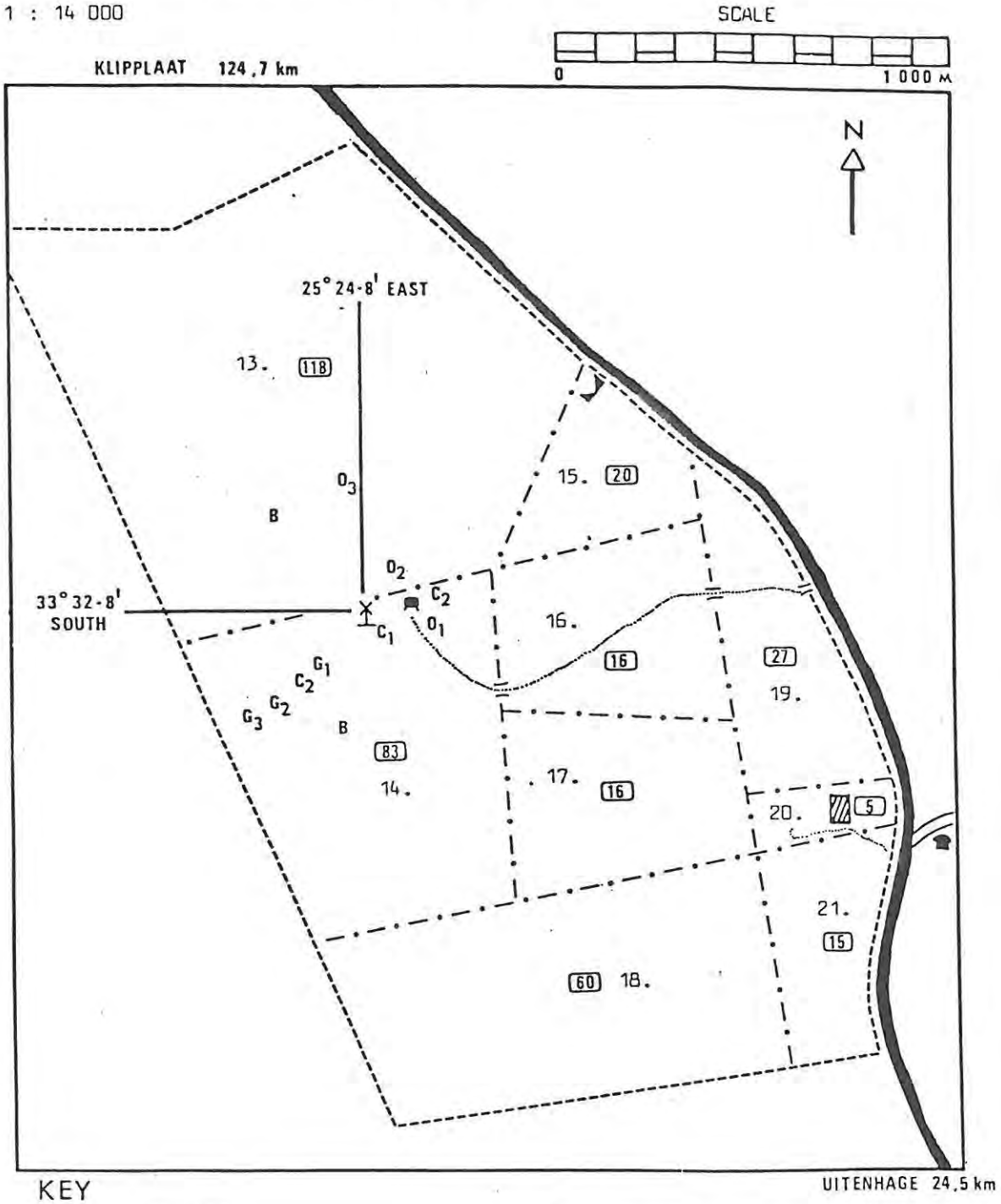
* See acknowledgements

MAP 1 The Brakhill study area - Kudu camp.

1 : 14 000

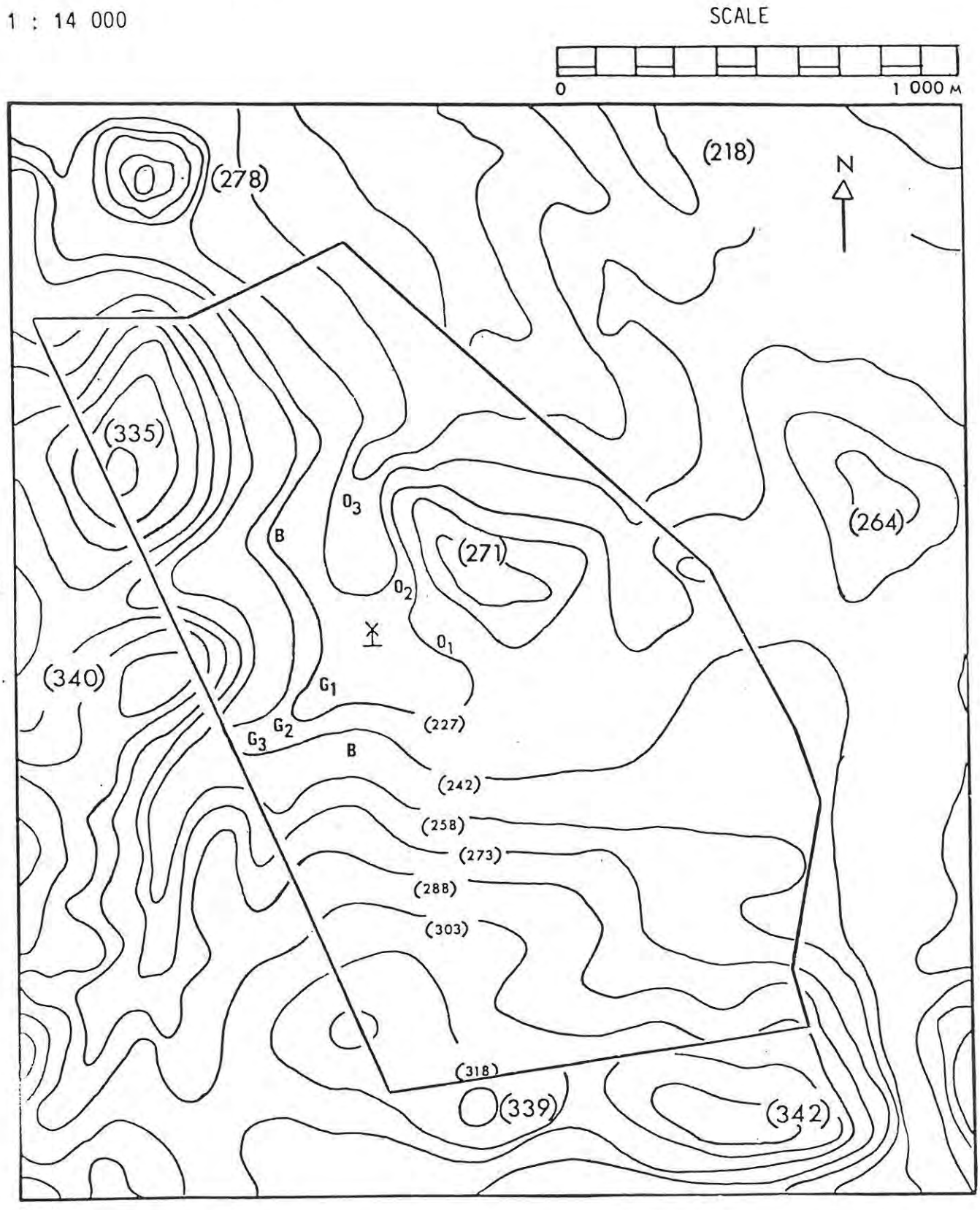


KEY

- Windmill
- Tracks
- Game fence
- Stock fences
- Farmhouse
- Kraal
- Arterial road
- Secondary road
- Reservoir
- Research caravan
- Plot area in hectares
- X. Plot number
- C_1 Thermohygrograph
- C_2 Temperature recording sites
- $O_1 - O_3$ Open 'drag' sites
- $G_1 - G_3$ Gully 'drag' sites
- B Bush 'drag' sites

MAP 2 A contour map of Kudu camp.

1 : 14 000



KEY

(x) Height in meters

O_1 - O_3 Open 'drag' sites

B Bush 'drag' sites

G_1 - G_3 Gully 'drag' sites

Windmill

argentea, Azima tetracantha and other plants of this association. Included in this ecosystem are pockets of over-exploited, open, low scrub and herb growth, often dominated by Cynodon incompletus, and presumably, judging by the remains, interlocking matted plants of Galenia sp. and Atriplex semibaccato or of Psilocaulon sp.

Acocks (1975) considers Fish River Scrub as a subsection of Valley Bushveld. There is, however, little or no overlap in species composition for the major elements of Fish River Scrub and Southern Valley Bushveld (Cape Province type). Southern Valley Bushveld has, for example, tall Euphorbia species such as E.triangularis, and includes much more commonly Grewia occidentalis than G.robusta, while Portulacaria afra is usually completely absent. The facies of the vegetation also differs with Southern Valley Bushveld being a much taller and less evenly canopied type than Fish River Scrub. Between the two types, which often lie almost contiguously, there is generally a narrow grass-dominated band along the contour, separating the higher altitude Southern Valley Bushveld from the lower-lying Fish River Scrub.

Black (1901) makes mention of this dividing grassland strip in discussing the Great Fish River area. He states:- 'The river runs in a vast valley, bounded by grass-covered hills, which are in numerous places from twelve to sixteen miles or more apart, and it is this entire valley that is covered with bush'. Dyer (1937), in discussing scrub and bush, states that bush differs from scrub primarily in its physiognomy. He considers bush the transitional stage between scrub and forest. With the grassland strip between, Southern Valley Bushveld and Fish River Scrub can then be considered distinct, given the differences in major plant constituents.

In the area examined, besides the indigenous species present, there are a large number of exotic weeds, mainly Opuntia aurantiaca (jointed cactus) and O.ficus-indica (prickly pear) as well as small herbaceous species for example Chenopodium henopodium album.

The grazing potential of the area is low but browsing material is plentiful.

3. CLIMATE AT KUDU CAMP

3.1 INTRODUCTION

An objective of the study was to examine the possible relationship between climate and tick occurrence. Sutherst, Wharton & Utech (1978), in a Guide to Studies on Tick Ecology, emphasize the importance of acquiring suitable meteorological data. This is because the major mortality factors for tick species are temperature and desiccation, ticks being 'strikingly free of important parasites, pathogens and predators' (Sutherst *et al.*, 1978).

Climate in this study refers primarily to rainfall, temperature and humidity. This section is a presentation and evaluation of recordings made from February 1981 until March 1982 (rainfall was recorded until July 1982). This information is then related to studies on free-living larval life stages (Section 4), and life stages parasitic on goats (Section 5).

3.2 METHODS AND MATERIALS

A thermohygrograph, shown as C_1 on Map 1, housed in a Stevenson's screen was used to monitor weekly relative humidity and temperature. A mercury maximum/minimum thermometer was placed in the screen and a rain gauge fixed to the top of the windmill above the thermohygrograph.

A prior examination of daily climatic records at Kudu camp, showed that the highest temperature and lowest humidity were recorded between 13h00 and 15h00. The lowest temperature and highest humidity were recorded between 06h00 and 08h30. At 20h00 intermediate conditions prevailed.

Because of this information 3 recording times were selected, viz. 08h00, 14h00 and 20h00.

In addition to the thermohygrograph field recordings were made in order to provide a more accurate estimation of conditions in possible tick microhabitats.

Recording sites were selected in an attempt to meet 3 requirements:

i) To represent temperature variability in the study area.

ii) To allow rapid recordings since extensive and time consuming sampling for free-living larvae had to be undertaken (Section 4).

iii) To provide temperatures representative of vegetational areas occupied by free-living ticks.

Three regions were selected for the establishment of field recording sites (Maps 1 and 2):

i) Open sites (O)

These had no large bush cover and had low vegetation of uniform height rarely exceeding 5cm in height.

ii) Gully sites (G)

Consisting of small bush and grass with partial tree and bush cover on the gully edge. Vegetation rarely exceeded 20cm in height.

iii) Bush sites (B)

Consisting of dense bush exceeding 20cm in height with pockets of grass and small bush beneath a canopy reaching 3 to 4m in height.

Two recording sites were sited in each area. Open and gully sites were established in February 1981 and bush sites in June 1981. Details concerning field recording sites are listed in Table 1.

TABLE 1 Field sites selected for temperature recordings at Kudu camp (shown as positions C_2 on Map 1).

Site	Number	Gradient	Aspect	Sunshine
Open	1	flat	-	all day
Open	2	flat	-	all day
Gully	1	flat	-	afternoon
Gully	2	flat	-	morning
Bush	1	slope	south-east	morning
Bush	2	slope	north-west	afternoon

From March until June 1981 a Rotronic Hygroskop BT Humidity and Temperature recording meter with probe type KG-HT was used for field site recordings. Dowling with screws inserted to enable readings to be made at 1,3,10 and 20cm above the substrate was inserted in the soil at the 6 sites. Several problems with this method arose. Dowls even in 'concealed' positions were broken by stock and game and the time taken to record humidity and temperature prolonged larval sampling periods excessively. Table 2 presents a summary of recordings of relative humidity made from March 1981 until June 1981. Within site recordings at 1,3,10 and 20cm above the substrate were not significantly different.

TABLE 2 A comparison of relative humidity (%) within field recording sites and between field recording sites and the thermohygrograph at Kudu camp.

Date	Sites mean	Within sites		Between sites		Thmgrph	T - S
		SD	range	SD	range		
TIME: 08h00							
10.03.81	51	.8	2	7	40 - 60	65	14
17.03.81	52	.9	2	5	46 - 62	70	18
24.03.81	No recording; meter recalibrated						
07.04.81	88	0	0	3	83 - 92	90	2
28.04.81	78	0	0	1.1	77 - 80	77	-1
05.05.81	81	0	0	0	0	85	4
11.05.81	80	0	0	0	0	85	5
18.05.81	83	0	0	0.7	82 - 84	85	2
25.05.81	83	0	0	0	0	85	2
03.06.81	91	0	0	1	90 - 92	90	1
08.06.81	90	0	0	0	0	90	0
TIME: 14h00							
10.03.81	34	.4	1	1.4	32 - 36	40	6
17.03.81	27	0	0	0.9	26 - 28	30	3
24.03.81	No recording; meter recalibrated						
07.04.81	64	0	0	1.2	63 - 66	60	-4
28.04.81	62	0	0	4	57 - 66	57	-5
05.05.81	29	0	0	1.9	27 - 32	25	-4
11.05.81	53	0	0	1.6	52 - 56	55	2
18.05.81	54	0	0	0.8	53 - 55	60	6
25.05.81	37	0	0	1.8	35 - 39	35	-2
03.06.81	63	0	0	2.6	60 - 66	65	2
08.06.81	62	0	0	2	59 - 64	65	3
TIME: 20h00							
10.03.81	57	0	0	0	0	65	8
17.03.81	62	0	0	0.4	62 - 63	70	8
24.03.81	No recording; meter recalibrated						
07.04.81	67	0	0	2.7	65 - 71	65	2
28.04.81	80	0	0	0	0	77	-3
05.05.81	56	0	0	2.3	53 - 58	60	4
11.05.81	85	0	0	0	0	85	0
18.05.81	68	0	0	2.3	66 - 71	70	2
25.05.81	45	0	0	2.4	42 - 48	45	0
03.06.81	79	0	0	2.1	76 - 81	80	-1
08.06.81	69	0	0	1.0	68 - 70	75	6
KEY						T - S mean n = 30	2.9 (SD 4.9)
						T - S mean n = 24	1 (SD 3.0)

Sites = open and gully sites
SD = standard deviation
within site SD = site recording with the largest SD
within site range = site recording with the largest range
Thmgrph = thermohygrograph
T - S = thermohygrograph reading - mean site reading.

Differences in relative humidity between sites were greater than within sites as indicated by the larger between site standard deviations listed in Table 2. Considering an instrumental error of $\pm$ 5% these between site differences were still small. A comparison of mean site recordings at 08h00, 14h00 and 20h00 with those recorded at the thermohygrograph showed a mean higher humidity reading of 2.9% (SD = 4.9; n = 30) at the thermohygrograph. Disregarding the 2 recording periods prior to the recalibration of the recording meter, the thermohygrograph showed a mean higher reading of only 1.0% (SD = 3; n = 24). Because of these results and previously mentioned problems, field site recordings of humidity were discontinued, as thermohygrograph recordings were considered to represent microhumidity adequately.

Since differences in temperatures recorded between sites, and between sites and the thermohygrograph were larger than the differences in humidity, field recordings of temperature were continued. Temperature was recorded with a mercury thermometer (-10°C to +50°C). Temperature differences within field sites were all within the instrumental error of $\pm$ 1.5°C and therefore only one height was selected for continued recordings. A height of 3cm was selected because heights of 10 and 20cm were above the short, open site vegetation and recordings at a height of 1cm were more likely to be adversely affected by ground temperatures.

Dowling was replaced with short solid wooden pegs with holes drilled to accommodate the mercury thermometer at 3cm above the substrate. Recording procedure was to take readings at the predetermined times and then proceed with larval sampling.

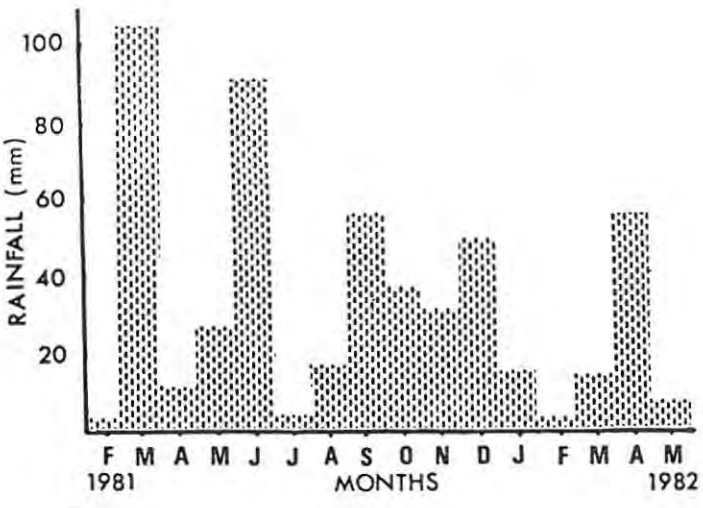
A subjective assessment of the presence or abscence of wind was made during weekly sampling. Winds were classed as either 'cool' or 'berg' winds (Table 3.4).

3.3 RESULTS AND DISCUSSION

3.3.1 Rainfall

Rainfall for the 'year' February 1981 to January 1982 was 444mm (Table 3.1). This was 144mm in excess of a mean annual rainfall of ±300mm. The seasonal rainfall in 1981 was higher in autumn and winter (117 and 121mm respectively) than in spring and summer (110 and 96mm respectively). This was due to the high rainfall in March (105mm) and June (91mm)(Table 3.1 and Graph 1).

GRAPH 1 Monthly rainfall (mm) recorded at Kudu camp (February 1981 to May 1982).



Disregarding these months of high rainfall, autumn and winter were generally periods of lower rainfall than spring and summer during 1981 (Table 3.1).The rainfall in autumn and winter in 1982 was 124mm which was considerably lower than the 238mm recorded over the same period in 1981.

3.3.2 Relative humidity

Relative humidity was highest at 08h00, lowest at 14h00 and intermediate but high at 20h00. The mean seasonal humidities at 08h00, 14h00 and 20h00 listed in Table 3.2 were in the region of 80%, 40% and 70% respectively. The small degree of overlap in Graph 2.1 indicates that the relative humidity was generally consistently different at the 3 recording times throughout the year. Graph 2.2 shows that seasonal humidity was lowest in summer and highest in autumn and winter. Despite monthly fluctuations (Graph 2.1), seasonal humidity at the 3 recording times and especially at 20h00 showed little major fluctuation throughout the year.

3.3.3 Atmospheric temperature

A maximum temperature of 44°C was recorded during December 1981. The lowest temperature recorded was -5°C in July. Graph 3.1 shows that except for June, July and August 1981 and May 1982, mean maximum temperatures were high and ranged between 30°C and 40°C from February 1981 until April 1982. Mean seasonal temperatures (Graph 3.2 and listed in the lower section of Table 3.3) indicated high summer temperatures of 20°C at 08h00, 31°C at 14h00 and 23°C at 20h00. High winter temperatures at these recording times were considerably lower being 8°C, 20°C and 10°C respectively. In autumn and spring intermediate temperatures were recorded.

The upper section of Table 3.3 lists the mean highest and lowest temperatures recorded from the field sites while temperature trends at these sites are shown in Graph 4. Additional axes have been added for purposes of comparison. At all 6 field sites monthly temperature trends were generally similar although some differences indicated in Graph 4 between sites require discussion.

In June and July 1981 temperatures recorded at 08h00 in open and gully sites were lower than those recorded at the bush sites (Graph 4). This is explained by heavy condensation on gully and open site vegetation compared with less dew on vegetation under the bush canopy. Conversely, temperatures recorded in June at 14h00 were lower at the bush sites than those recorded at the open and gully sites. The latter difference was probably due to the fact that oblique winter sunlight was less effective in penetrating bush vegetation. The highest temperatures were recorded at 14h00 at the open sites and bush site 2 during December. An explanation for this result was the exposed nature and 'all day' sunlight experienced at open sites, and the north-westerly facing slope on which bush site 2 was situated.

Temperatures recorded at open sites were possibly less extreme than might have been expected. Map 2 shows that open sites were closest to the eastern hill in the study area and therefore received morning sunlight later in the day than the other sites. Unexpectedly open site 1 with cleared vegetation experienced mean monthly temperatures no different from those recorded at open site 2 with intact vegetation. Because only $20cm^2$ of vegetation was cleared, open site 1 may still have been subjected to the microclimatic effects of surrounding vegetation.

In addition the very short vegetation at open site 2 would probably have afforded little protection from the air temperatures above it.

The thermohygrograph, although indicating microclimatic temperatures, generally did not measure microclimatic extremes accurately. The differences between the thermohygrograph readings and field site temperatures varied according to daily and seasonal recording times. The maximum difference between thermohygrograph and field site temperatures was 6°C at 08h00, 7°C at 14h00 and 3°C at 20h00. The mean monthly maximum difference was 2.8°C at 08h00 (range 1-6, SD 2.1), 3.1°C at 14h00 (range 1-7, SD 2.1) and 1.1°C at 20h00 (range 1-3, SD 1.1). Therefore recordings at 20h00 at the thermohygrograph most closely approximated those at the field sites. As one would expect differences in temperature were greatest at 08h00 and 14h00, periods when temperatures were extreme. At 08h00 differences were most marked from July until November and at 14h00 from November 1981 to January 1982 as shown in Graphs 5.1 and 5.2. Graphs 5.1 and 5.2 indicate that at 08h00 the thermohygrograph recordings were considerably lower than mean field site microtemperatures from midwinter to spring, and at 14h00 from late spring to midsummer. At 08h00 from midwinter to spring seasonal temperatures were cool, the sun further north and sunrise later. The short period of morning sun falling on the field sites before 08h00 probably had a marked effect on the temperature compared with that of the sheltered thermohygrograph. By 14h00 temperatures had equated. From late spring to midsummer temperatures were higher, the sun more directly overhead and sunrise earlier. By 08h00 the thermohygrograph and field sites had experienced several hours of sunshine and temperatures were similar.

At 14h00 temperatures were high and field sites warmer compared with the thermohygrograph protected from the overhead sun by the Stevenson's screen.

Graph 5.3 shows that at 20h00 during summer the thermohygrograph recordings were higher than mean field site microtemperatures. These higher readings may have been due to a less rapid heat loss from the thermohygrograph compared with ground surfaces.

Another possible factor accounting for the differences in temperature between the thermohygrograph and field sites was wind. Table 3.4 summarizes the monthly occurrence of cool and berg winds recorded during weekly sampling. Without continuous quantitative information on wind direction, duration, velocity and temperature no detailed discussion on the effects of wind on climate is possible. The results indicate that there was wind in all months and particularly from July to December when warm berg winds occurred. Generally wind would, at least initially, produce greater differences in temperature between 'exposed' field sites compared with the sheltered thermohygrograph.

TABLE 3 Climatic information recorded at Kudu camp (February 1981 to May 1982).

3.1 Rainfall (mm).

Year	1981												1982					
Season	AUTUMN			WINTER			SPRING			SUMMER			AUTUMN			WINTER		
Month	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
Rainfall	1	105	11	27	91	3	17	56	37	31	50	15	3	14	56	6	28	17
Low monthly rainfall (< 20mm)	1		1			3	17					15	3	14		6		17
High monthly rainfall (> 30mm)		105			91			56	37	31	50				56			
Seasonal rainfall	117			121			110			96			73			51		
Annual rainfall	444												124					

3.2 Mean relative humidity (%) recorded at the thermohygrograph at selected times.

SITE	TIME																	
	08h00					14h00					20h00							
	max(m)		min(m)	mean	SD	max(m)		min(m)	mean	SD	max(m)		min(m)	mean	SD			
Thgrph	83 (Ap)		70 (O)	78	5	52 (Ap)		28 (O)	40	7	88 (Ju)		59 (F)	69	7			
Season	A	W	SP	S	A	A	W	SP	S	A	A	W	SP	S	A			
Mean	82	79	76	75	80	44	42	37	36	42	67	79	69	65	69			
SD	8	14	12	6	4	12	10	12	9	8	10	9	12	15	8			
n = 12																		

KEY

O 1,2 = Open sites 1 and 2
G 1,2 = Gully sites 1 and 2
B 1,2 = Bush sites 1 and 2

Thgrph = Thermohygrograph
(m) = (month)
SD = Standard deviation

TABLE 3.3 Mean temperatures (°C) recorded at the thermohygrograph and field sites at selected times.

SITE	TIME															
	08h00					14h00					20h00					
	max(m)		min(m)			max(m)		min(m)			max(m)		min(m)			
O 1,2	22,25(Ap)		6(Ju)			40(D)		18,19(Ju)			25(F)		10,11(Ju,Jl)			
G 1,2	25,28(Mr)		6(Ju/Jl)			37,39(D)		18,19(Ju)			24,25(F)		10(Ju/Jl)			
B 1,2	26,23(F)		10,12(Ju,Jl)			37,41(D)		13,19(Ju)			24,25(F)		7,9(Ju)			
Thgrph	21(J/F)		6(Ju)			36(F)		19(Ju)			25(F/Mr)		7(Ju)			
Season	A	W	SP	S	A	A	W	SP	S	A	A	W	SP	S	A	
Mean	16	8	13	20	15	29	20	26	31	23	19	10	15	23	19	
SD	5	3	4	2	5	5	3	5	6	9	4	3	4	5	4	
n = 12																

3.4 Wind recorded at Kudu camp.

Year	1981											1982				
Month	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Cool winds	1	1	1	2	1	1	1	1	1	3	1	1	1	1	1	0
Berg winds	0	0	0	0	0	2	0	1	1	1	1	0	0	0	0	0
n = 4																

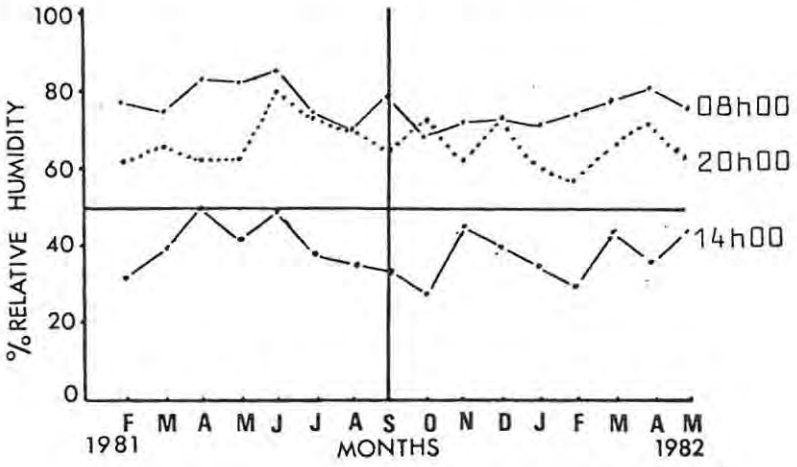
KEY

O 1,2 = Open sites 1 and 2
G 1,2 = Gully sites 1 and 2
B 1,2 = Bush sites 1 and 2

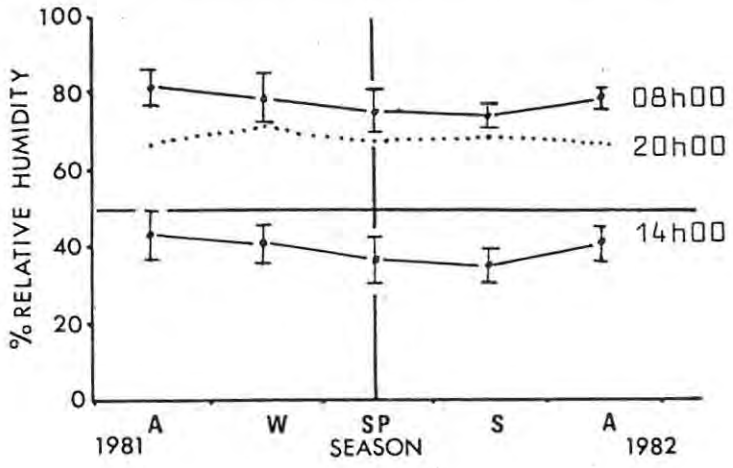
Thgrph = Thermohygrograph
(m) = (month)
SD = Standard déviation

GRAPH 2 Mean % relative humidity recorded at 3 times of the day at the thermohygrograph in Kudu camp from February 1981 to May 1982.

2.1 Monthly relative humidity.



2.2 Seasonal relative humidity.

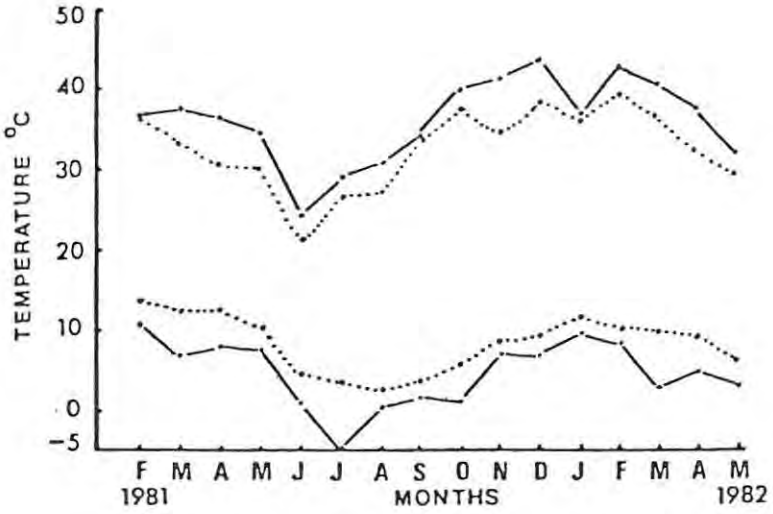


KEY

I = Standard deviation

GRAPH 3 Major temperature trends recorded at Kudu camp from February 1981 to May 1982.

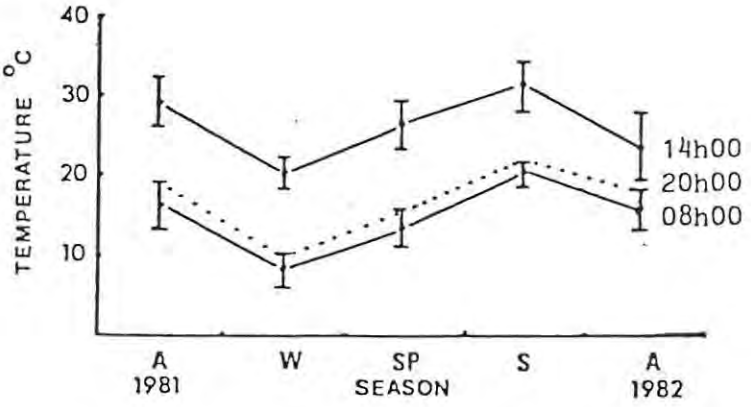
3.1 Maximum and Minimum temperature.



KEY

.... = mean monthly maximum and minimum temperatures
—— = the highest and lowest temperatures recorded each month

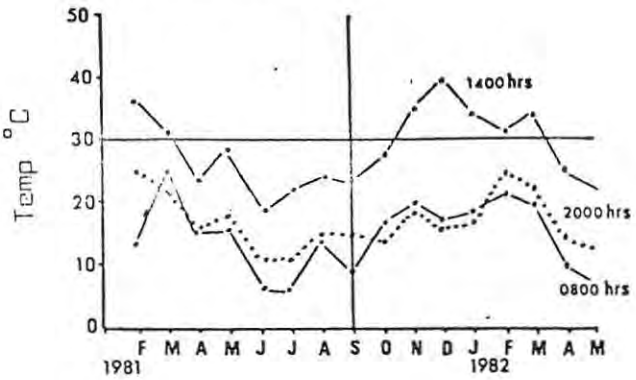
3.2 Seasonal temperature



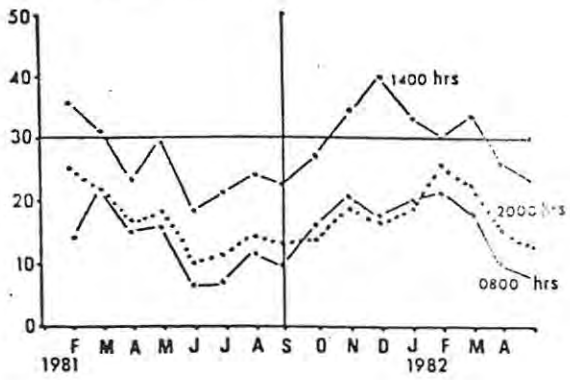
KEY I = Standard deviation

GRAPH 4 Mean monthly temperatures recorded at 3 times of the day at 6 field sites in Kudu camp (February 1981 to May 1982).

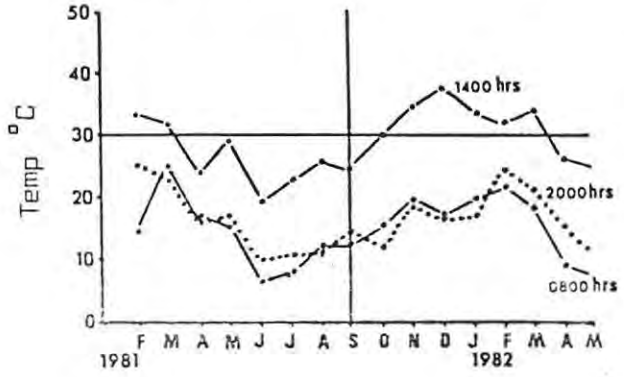
4.1: Open Site 1



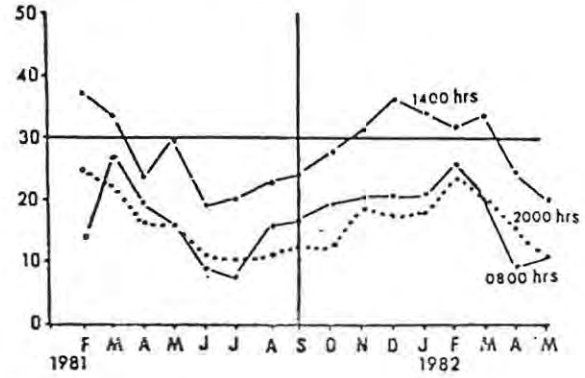
4.2: Open Site 2



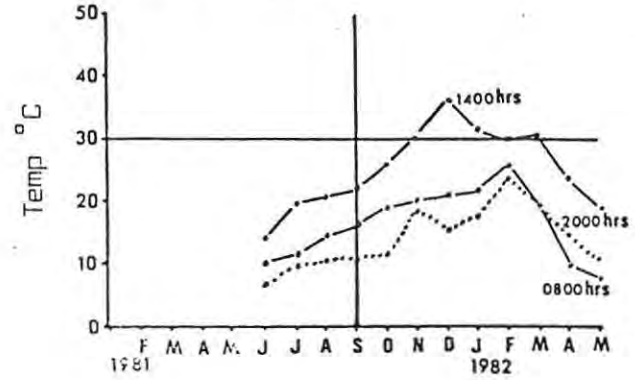
4.3: Gully Site 1



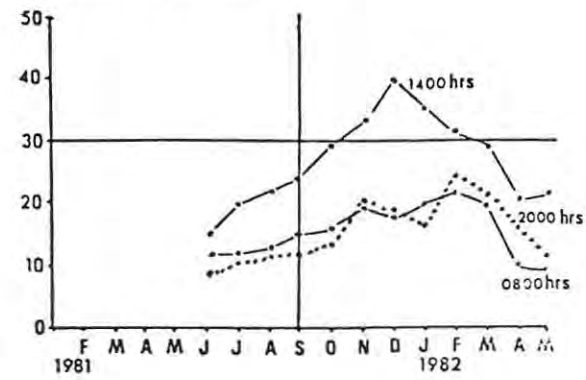
4.4: Gully Site 2



4.5: Bush Site 1

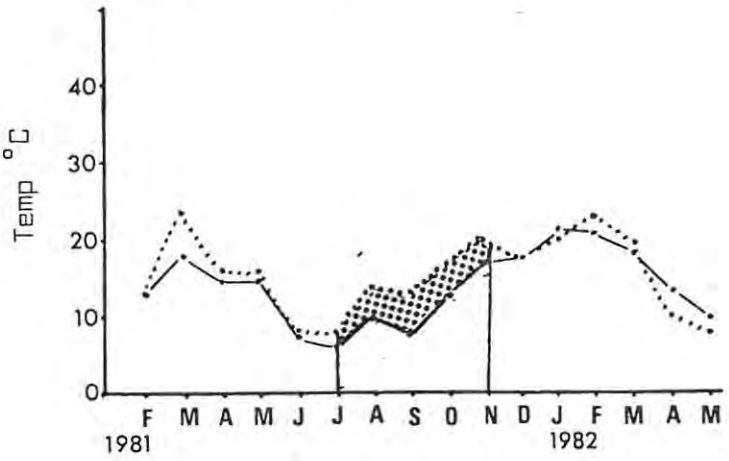


4.6: Bush Site 2

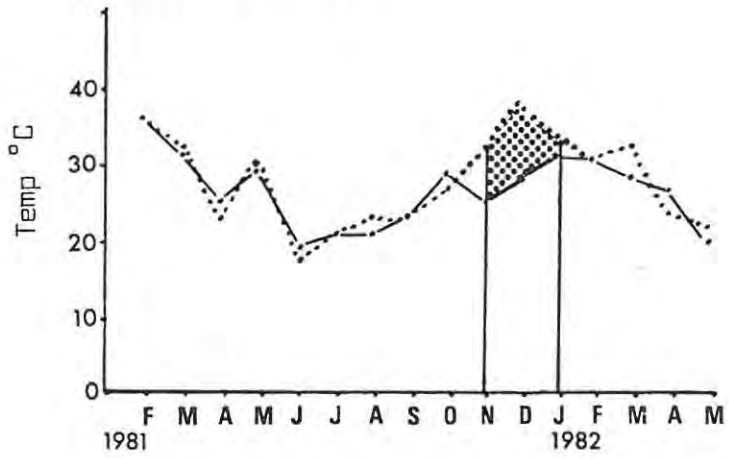


GRAPH 5 A comparison of mean monthly temperatures (°C) recorded at the thermohygrograph and 6 field sites at Kudu camp from February 1981 to May 1982.

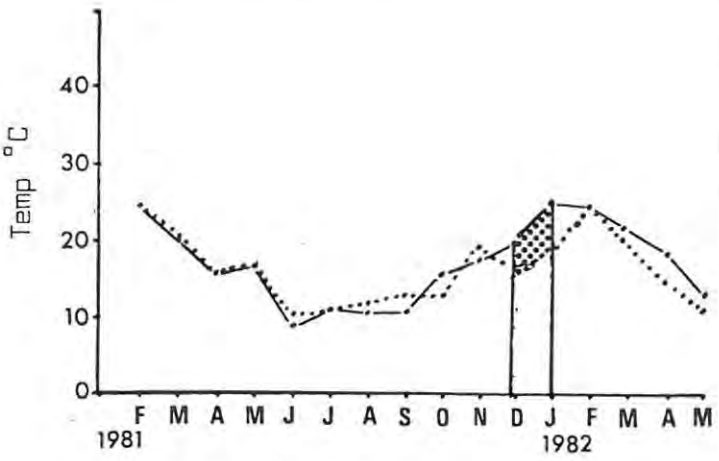
5.1: At 08h00.



5.2: At 14h00.



5.3: At 20h00.



KEY

—·—·— = mean temperature at the thermohygrograph

····· = mean temperature at 6 field sites

▒ = area of maximum discrepancy

4. STUDIES ON FREE-LIVING LARVAE

4.1 INTRODUCTION

Previous survey work in the area failed to reveal the presence of R.glabroscutatum immatures (Rechav,pers.comm.,1981), thus a primary objective of the study was to locate free-living larvae of this tick species. An appraisal of sampling methods was necessary because no records of free-living larvae were available.

4.2 METHODS AND MATERIALS

4.2.1 Sampling apparatus

Rechav (1979) citing Norval (pers. comm.), and citing Rechav & Whitehead (1978) stated that in the eastern Cape Province carbon dioxide and pheromone traps were found to be inefficient as they were effective over short distances only. It was therefore decided that the 'flagging' or 'dragging' method (Stampa, 1959) in which linen tails are pulled over vegetation would be adopted.

The apparatus used consisted of a 1m long dowl with 9 white linen tails (0.1m x 1.0m) which were fastened to closed hooks along the dowl by means of safety pins. A smaller dragging apparatus a third as wide as the one described with only 3 linen strips was later constructed to conduct certain selected sampling (see Table 5). Both sets of apparatus were pulled over vegetation by the operator by means of a cord attached to the dowl ends.

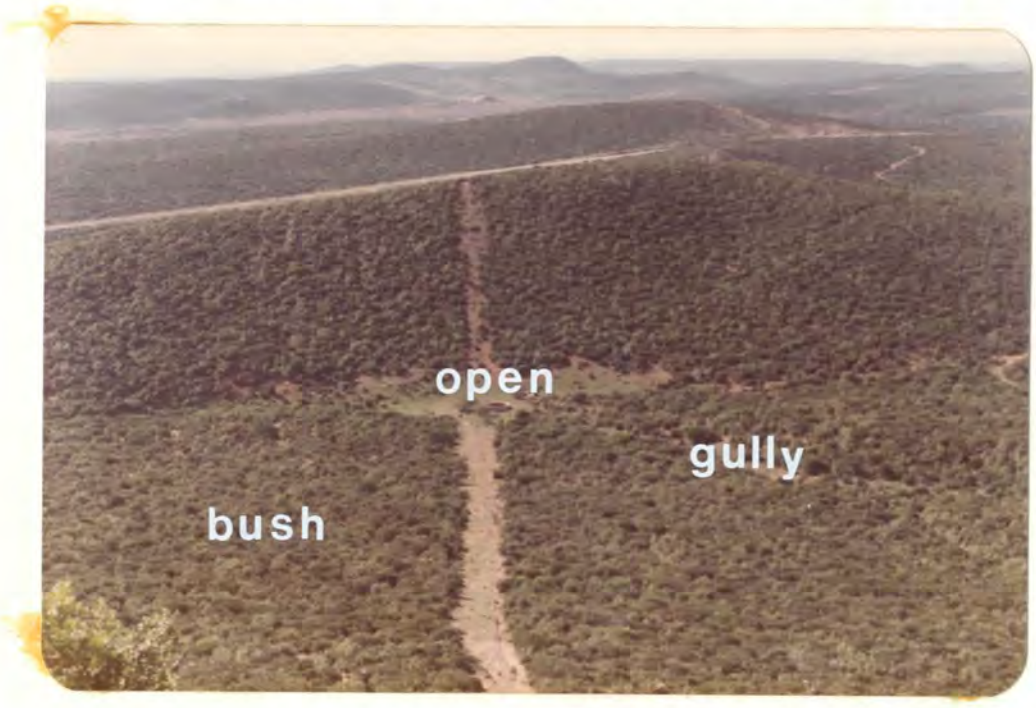
4.2.2 Sampling methods

The following factors were considered important with regard to sampling methods: sample site, sampling time (the duration of sampling and the time at which sampling took place), distance over which sample was collected, sample type ('random' or 'fixed') and the method and place of larval collection.

(i) Sample site

The sampling sites were clearly indicated by vegetational differences and were located in bush, gully and open areas (Plate 1).

PLATE 1 The study area, Kudu camp showing bush, open and gully areas.



(ii) Sample time

The three daily sampling times selected on the basis of initial temperature and humidity recordings (Section 3) were 08h00, 14h00 and 20h00.

Table 4 lists the general differences in relative humidity, temperature and light at these times. Actual sampling took place within half an hour of the given sampling times.

TABLE 4 Sampling times selected with regard to temperature, relative humidity and light in Kudu camp.

SAMPLING TIMES	08h00	14h00	20h00
Temperature	low	high	intermediate
Humidity	high	low	intermediate
Light intensity	low	high	zero

(iii) Sampling distance and measurement

Two factors to be considered were the accuracy of measurement of the area sampled and the standard distance over which the samples were to be collected. It was considered essential that accurate sample area measurements be made since site and time comparisons were desired and accurate measurement would reduce variation in relative abundance caused by variation in sample area.

The 'pacing' method in which an operator walks a set number of steps (often 50) and equates these to the equivalent number of meters has been widely adopted in drag sampling (Londt & Whitehead, 1972; Norval, 1975).

The problem with this method is that pace length may vary with the operator, gradient, conditions underfoot and during night time sampling. In studies where the relative abundance of free-living larval stages is relatively high this possible source of variability may be permissable. However, at Kudu camp sampling methods were designed on the assumption, based on previous survey work, that larval abundance would probably be low. Consequently it was decided to conduct drags over the longest practical distance to improve the chances of making larval catches. Drag length was limited by the size of the 3 open areas which were smaller than the gully and bush areas.

(iv) Random or 'fixed' drags

Once a drag site had been accurately measured and sampled this procedure could have been repeated at a different site on every sampling occassion or the pace method adopted (random dragging). The alternative was to conduct repeated sampling in the same area (fixed dragging).

The advantages of the fixed drag method are accuracy of the sampling distance and more precise vegetational knowledge since set areas may be examined at any time with respect to vegetation height or type. When the random dragging method of sampling is adopted to estimate free-living larval abundance, and variations in relative abundance within selected areas occur, these variations may be ascribed to vegetational heterogeneity. The use of the fixed drag method whereby the same vegetational areas are sampled is a means of reducing this heterogeneity. An additional factor promoting vegetational homogeneity in Kudu camp was the continual grazing by goats and other animals of gully and open area vegetation. Heights of vegetation in the sample area throughout the study were within the limits stated in section 3.2.

Possible problems associated with fixed dragging could have been unnatural path formation, the depletion of larval populations (i.e. a continual drop in relative abundance), and unrepresentative sample catches in a 24 hour period due to fixed order sampling times.

Path formation was prevented by walking next to the sample area with the arm holding the cord of the dragging apparatus extended over the area to be sampled.

Since the gully and open areas were relatively small compared to the bush area (Plate 1) depletion of tick populations by repeated sampling (random or fixed) could in any event have occurred. Repeated random sampling in gully and open areas would have led to drags overlapping and this degree of overlap would not have been measurable unlike the total overlap which is an integral part of the fixed drag method.

The sampling time order was altered in 1982 in order to determine the effect of sampling time order on catch size in a 24 hour period. In 1981 the order of sampling times was 14h00, 20h00 and 08h00 and in 1982 it was 20h00, 08h00 and 14h00.

(v) The method of larval collection from linen strips

Due to the small size of R.glabroscutatum larvae, the method whereby ticks were located on the linen drag strips was regarded as important.

Once a drag sample had been conducted the apparatus was hung from hooks inside the field site caravan so that the strips hung free.

This was to prevent the dislodgement of larvae due to chance mechanical disturbance.

The removal of larvae from strips in the field had several disadvantages. The time taken to conduct sampling was a function of the number of larvae picked up. When this number became large the maintenance of relatively accurate sampling times was difficult.

There was probably a detection bias against a small tick like R.glabroscutatum in the presence of a relatively large species such as Amblyomma hebraeum (which was numerous in drags). This may have been especially important in poor light and the resultant sample could have indicated an unrepresentative proportion of 'large' to 'small' species.

It is probable that not all larvae were removed from drag strips in the field. On several occassions a 'cleaned' tail was found to have previously undetected larvae on it. The intitial failure to detect these larvae could have been due to their small size, lack of movement (thanatosis), hidden position, poor light or inefficient examination by the worker. Reinfestation would also have been possible due to chance contact with an 'uncleaned' tail or from the dowl (where larvae were sometimes seen). Besides leading to an unrepresentative sample of relative abundance for a particular drag, undetected ticks could have been counted in a following drag.

In order to overcome these problems the following procedure was adopted. After completing a drag, tails were hung as described, individually removed, folded and placed in a labelled plastic bag which was sealed.

The dowl was wiped with tissue and a new set of strips fastened onto it. The next drag was then performed.

In the laboratory, at Grahamstown, the strips were unfolded on a cleaned surface and searched in good light. The surface on which the strips lay was examined and the bags inspected. Between sets of tail inspections the working surface was wiped clean.

It was found that the drag examinations needed to be conducted within 24 hours of sampling to prevent larvae from drying out. Dry specimens were more difficult to detect and identify. Ticks were placed in 70% alcohol and identified with the aid of a stereoscopic microscope (Nikon 102).

For confirmation of certain identifications and help with problem specimens ticks were sent to Miss Jane B.Walker at the Veterinary Research Institute, Onderstepoort.

4.2.3 The establishment of dragging sites

(i) Open and gully sites (fixed drags)

Three random routes of 100m were measured in the open areas taking care to avoid the interface between open ground and surrounding vegetation. In the gully area (Plate 2) 3 100m random sites were selected and included vegetation lying near animal paths, open areas of the gully and the interface between gully and bush vegetation. The 'interface' area was not in the thick bush but was partially covered by trees and bushes lining the gully's edge.

In both open and gully sites pegs and rock markers, painted bright yellow to aid in night sampling, were fixed along the routes selected.

PLATE 2 The gully site at Kudu camp with the 'dragging' apparatus in the foreground and experimental goats in the background.

(ii) Bush and control sites (random drags)

Fixed dragging using the wider dragging apparatus in the bush area produced no positive results. This was probably due to the width of the dragging apparatus that allowed only the wider paths between the bush to be sampled. Such paths had little or no vegetation. The smaller dragging apparatus was then used and proved to be satisfactory in reaching previously inaccessible areas under the bush canopy. The measurement of sample distances in the bush proved difficult because the bush area consisted of irregular pockets of vegetation. Random sampling (using the pacing method) of the bush area was therefore not strictly a random sample of the area but a random sample of pockets (ie. regions most likely to be tick infested).

Although a 300 pace sample was taken it was not possible to equate this to the actual sample distance covered. This was because the thick nature of the bush continually forced an altered sample sweep.

For these reasons no direct comparison of relative larval abundance between bush drags and those conducted at gulley and open sites was made.

Random drags were conducted at 14h00 in the open and gully regions outside the fixed 100m sections. These served as a control to ascertain possible larval depletion due to fixed dragging within the measured sections.

Table 5 summarizes the weekly dragging schedule. The total distance dragged per sampling occasion was approximately 2,3 km and the area covered represented 0,25% of camps 13 and 14 (Map 1) in which goats were kept.

TABLE 5 Weekly dragging schedule in Kudu camp.

Drag type	Distance	Area	Time of drag		
			08h00	14h00	20h00
Fixed	3 X 100m	Open (O)	X	X	X
Fixed	3 X 100m	Gully (G)	X	X	X
Random	300 paces	Bush (B)		X	
Random control	100 paces	Open (OC)		X	
Random control	100 paces	Gully (GC)		X	

4.2.4 Statistical methods

Analysis of variance (ANOVA) was conducted to consider the variables: sample site, daily sampling time, month of sample (within years) and year of sample. A log transformation of data was performed due to the inequality of variances between site/time groups and because a fixed percentage sample of a variable population results in a log function (Van Schalkwyk, pers. comm., 1982).The log transformation log (x + 1) was adopted since small and zero numbers of items were often recorded (Zahr 1974).

4.3 RESULTS AND DISCUSSION

4.3.1 Seasonal occurrence and associated climate

Table 6 and Graph 6.1 show that R.glabroscutatum larvae had defined periods of maximum relative abundance lasting 5 months in both 1981 and 1982. In 1981 this period lasted from April until August and in 1982 from February until June. It is possible that larvae were present outside recorded periods of relative abundance occupying habitats not reached by the sampling apparatus below the tops of the vegetation.

Graph 6.2 shows that the onset of larval occurrence was during months of low rainfall in April 1981 (11mm) and February 1982 (3mm). During the periods of maximum larval occurrence in 1981 and 1982 the monthly mean rainfall was 30mm (SD 35) and 21mm (SD 22) compared to monthly mean rainfall of 38mm (SD 16) from September 1981 to January 1982 when larval abundance was low.

TABLE 6 Free-living R.glabroscutatum larvae sampled at Kudu camp from February 1981 until August 1982.

YEAR		1981 △											1982 △							
MONTH		F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
Number of sites sampled		2	2	2	2	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Number of samples	08	2	4	2	1	1	1	1	2	2	2	2	2	2	2	2	1	1	1	1
	14	2	5	3	4	5	3	2	2	2	2	2	2	1	2	2	1	1	1	1
	20	2	2	2	3	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
	C	-	-	-	-	3	3	2	2	2	2	2	2	1	2	2	1	1	1	1
	B	-	-	-	-	3	3	2	2	2	2	2	2	1	2	2	1	1	1	1
Relative abundance		P1		P2					P1				P2					P1		
Results fixed drags G	08	0	0	1*, 4	1*	0*	0*	1*	0, 0	0, 0	0, 0	0, 0	0, 0	2, 1*	2, 2	0, 0	2	1	0	0
	14	0	0	10, 4*, 0	6, 5*, 1, 6	2, 1, 3, 5*, 2	3*, 6, 5	7, 2*	0, 0	0, 1	0, 0	0, 0	0, 0	7*	1, 1	0, 7	0	0	0	0
	20	0	0	12, 5*	23, 18*, 18	5*, 3	8*, 7, 17	17, 9*	0, 1	1, 0	0, 1	0, 0	0, 0	6*	11, 4	7, 14	10	2	0	0
O	08	0	0	0*, 1	2*	1*	4*	2*	0, 1	0, 0	0, 0	0, 0	0, 0	0, 1*	10, 4	0, 0	0	0	0	0
	14	0	0	0, 2*, 1	0, 2*, 2, 2	4, 2, 4, 9*, 5	2*, 8, 3	1, 0*	0, 0	1, 0	0, 0	0, 0	0, 0	7*	2, 0	0, 0	1	0	0	0
	20	0	0	4, 11*	12, 20*, 16	2*, 10	9*, 2, 23	13, 2*	0, 0	0, 0	0, 0	0, 0	0, 0	18*	10, 5	4, 40	8	49	1	2
Column statistics P2 only	W			55	134	58	97	54						42	52	72	21	52		
	n			14	16	16	14	10						8	12	12	6	6		
	$\bar{x}$			3.9	8.4	3.6	6.9	5.4						5.3	4.3	6.0	3.5	8.7		
	SD			4.2	8.0	2.8	6.2	5.9						5.9	3.9	11.6	4.4	19.8		
Results random drags	GC	-	-	-	-	1*, 3	1, 2, 0	3, 1	0, 0	0, 0	0, 0	0, 0	0, 0	1	0, 0	0, 1	0	0	0	0
	OC	-	-	-	-	0*, 0	2, 7, 1	0, 0	0, 0	0, 0	0, 0	0, 0	0, 0	0	1, 0	0, 0	2	0	0	0
	GC^C	-	-	-	-	9*, 27	9, 18, 0	27, 9	0, 0	0, 0	0, 0	0, 0	0, 0	9	0, 0	0, 9	0	0	0	0
	OC^C	-	-	-	-	0*, 0	18, 63, 0	0, 0	0, 0	0, 0	0, 0	0, 0	0, 0	0	9	0, 0	18	0	0	0
	B	-	-	-	-	0*, 0	2, 0, 0	10, 0	0, 1	1, 0	0, 0	0, 0	0, 0	1	0, 1	0, 1	0	4	0	1

Row Statistics					P2 only	
W	n	$\bar{x}$	SD		CV	CD
17	14	1.2	1.1		92	1.0
84	24	3.5	2.8		80	2.2
196	19	10.3	6.0		58	3.5
25	14	1.8	2.8		156	4.4
57	24	2.4	2.6		108	2.8
258	19	13.6	12.6		93	11.7

KEY (Table 6)

1981Δ = 1981 order of daily sampling 14h00, 20h00, 08h00.

1982Δ = 1982 order of daily sampling 20h00, 08h00, 14h00.

08 = 08h00

14 = 14h00

20 = 20h00

G = fixed gully area drag

O = fixed open area drag

GC = random gully area control drag

OC = random open area control drag

GC^C/OC^C = corrected control drags (correction factor X9 - Random controls covered a third of the distance and the cloth area of the apparatus used was a third of that of the large apparatus.)

B = bush area drag

P_1/P_2 = period of significatntly lower/higher relative abundance.

• = samples taken in the same 24 hour period in those months with uneven sample numbers

Σ = sum of

n = number of recordings

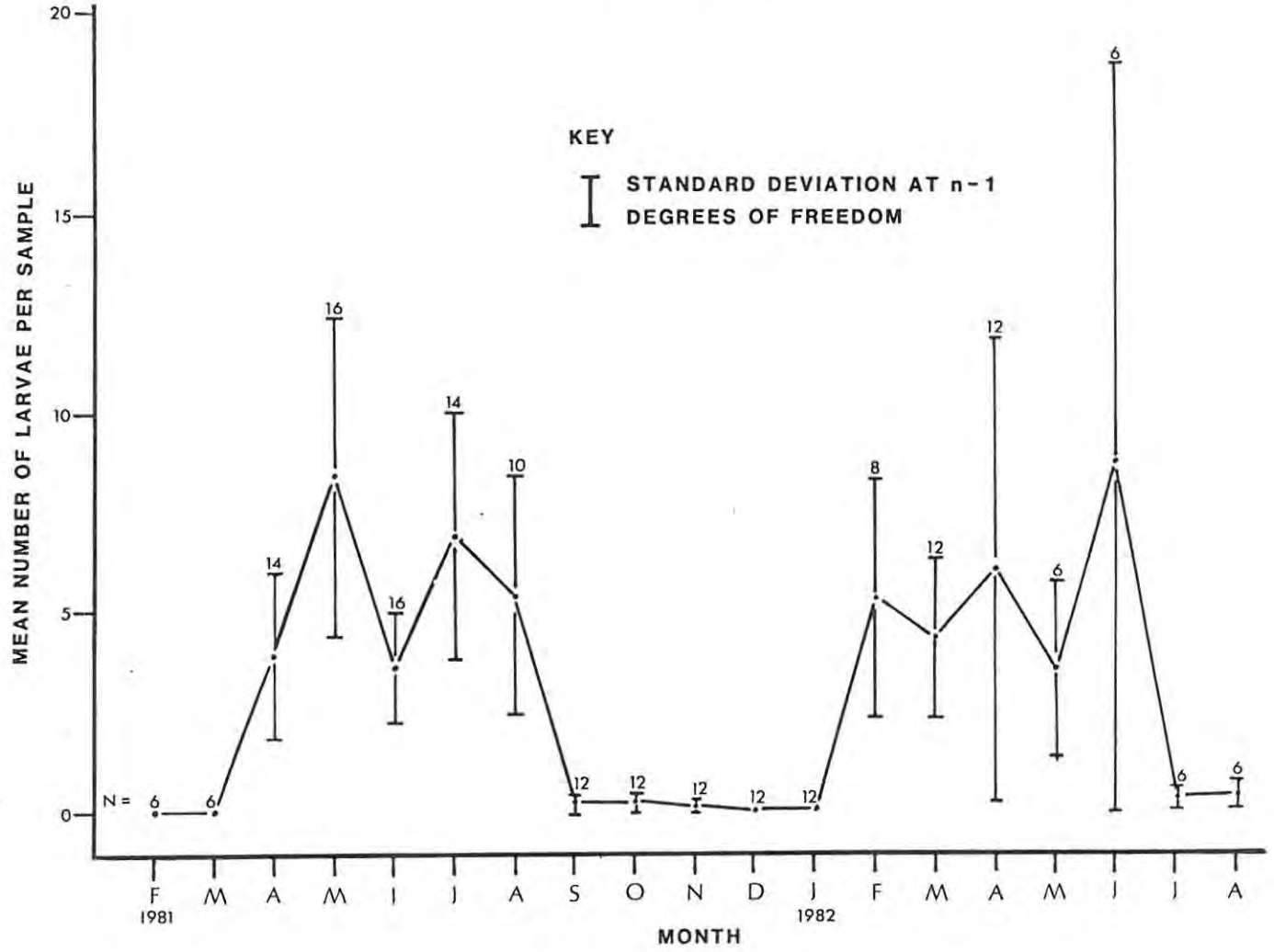
$\bar{x}$ = mean

SD (=S) = standard deviation with n - 1 degrees of freedom

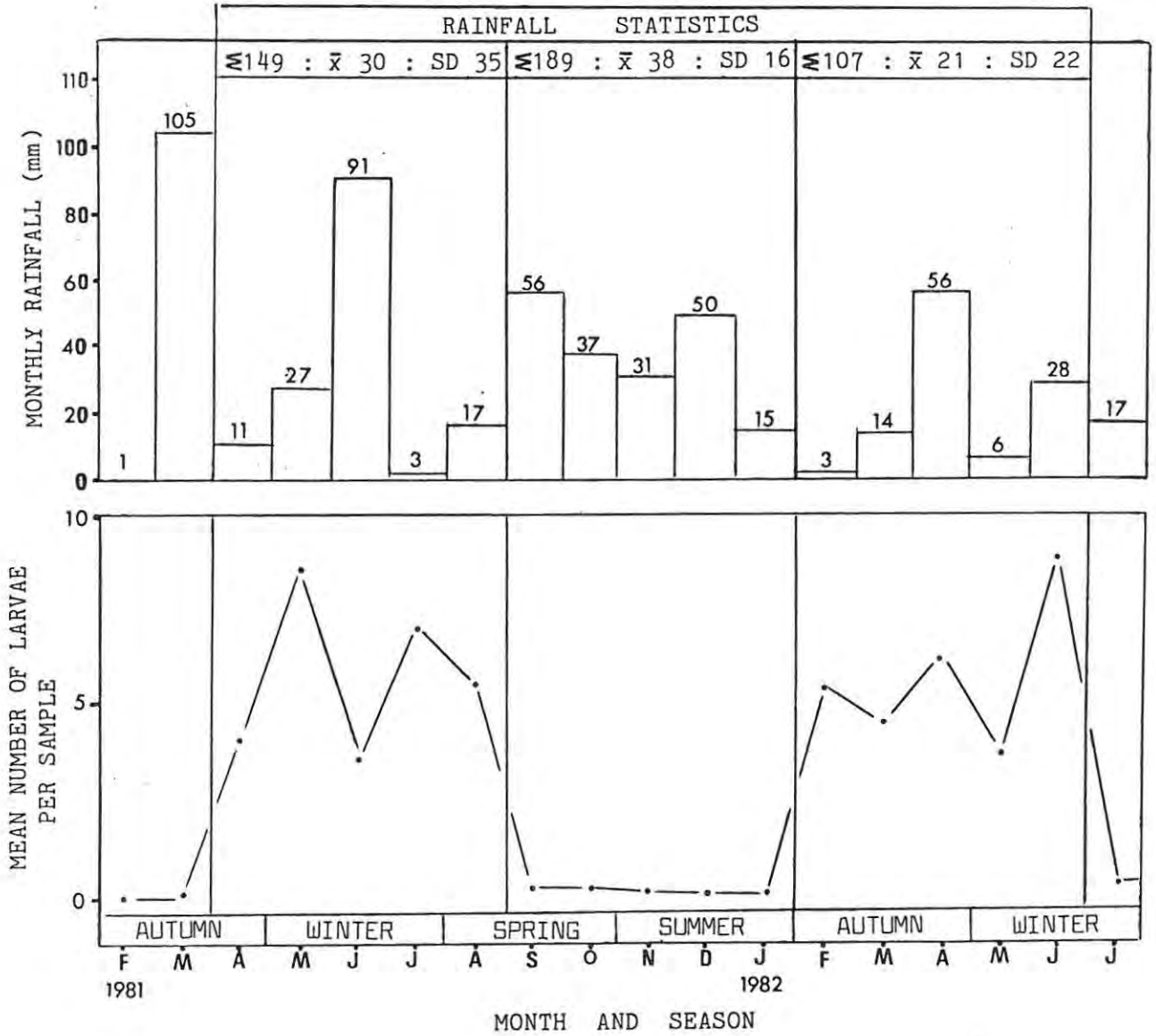
CD = coefficient of dispersion = $\frac{S^2}{\bar{x}}$

CV = coefficient of variation = $\frac{S \times 100}{\bar{x}}$

GRAPH 6·1 The mean number of free-living R.glabroscutatum larvae obtained per sampling occasion at Kudu camp (February 1981 to August 1982).



GRAPH 6.2 A comparison of rainfall with the relative abundance of free-living larvae at Kudu camp (February 1981 to July 1982).



The high standard deviations of 35 and 22 reflect the variability of rainfall during the winter and autumn periods when rainfall was generally low. This applied particularly to the late autumn to early spring period in 1981 when an atypical recording of 91mm was made in June in midwinter, which is usually a relatively dry period. From midspring to the end of summer, rainfall was consistently higher as indicated by a standard deviation of 16 about the mean of 38.

These results indicate that during 1981 and 1982 free-living larvae were abundant during periods of lower overall rainfall. The hypothesis that the distribution of R.glabroscutatum is related to rainfall is discussed further in Section 6 when distribution records for southern Africa are considered.

Autumn and winter in 1981 and autumn in 1982 were seasons with comparatively high mean relative humidities ((82%, 79% and 80% at 08h00; 44%, 42% and 42% at 14h00 and 67%, 79% and 69% at 20h00 respectively (Table 3.2)). Mean seasonal temperatures over the same period were intermediate to low ((16°C, 8°C and 15°C at 08h00; 29°C, 20°C and 23°C at 14h00 and 19°C, 10°C and 19°C at 20h00 (Table 3.3)). Autumn and winter were therefore periods during which larvae would have been exposed to the least climatic stress. This would be most important at midday when larvae would be subjected to the most extreme conditions of temperature and humidity.

4.3.2. Site and time comparisons using descriptive statistics

The relative abundance of R.glabroscutatum larvae in bush areas was low (Table 6). On one occassion (August 1981) there was a relatively large catch made in this region.

It is possible that this catch may have been made close to the gully/bush interface thus accounting for its magnitude. For the reasons outlined in section 4.2.3 no direct comparison of relative larval abundance between the bush and the other sites was possible.

The coefficient of variation (CV) presented as a row statistic in Table 6 indicated the amount of variation in the relative larval populations sampled at gully and open sites at 08h00, 14h00 and 20h00 in 1981 and 1982. Coefficients were high (range 58-156) suggesting large overall variation in sampled populations. This was supported by the large standard deviations evident in Graph 6.1. Within both gully and open sites there was a trend for the CV to be reduced in the order 08h00, 14h00 and 20h00, in addition gully sites had correspondingly lower CV values than open sites.

The coefficient of dispersion (CD) values shown in Table 6, with exception of the gully site at 08h00 (CD = 1), were greater than 1, indicating a clustered distribution of individuals. Numbers in table 6 indicated that the relative abundance of larvae per $300m^2$ ($3 \times 100m^2$) per sampling site/time was generally low (mean 5.2, standard deviation 8.2, range 0-49).

Given the above information it is important to consider possible reasons for the overall and between site/time variation in relative abundance obtained despite extensive attempts to reduce variation (Section 4.2). A low percentage sample of a population with a clustered distribution would generally result in higher variation than similar sampling of a population with a non-clustered distribution (Odum, 1971).

Variation in a 24 hour period would be increased if the population showed circadian activity patterns resulting in a varying number of individuals being available on vegetational surfaces for sampling in a 24 hour period. Variation would have been further increased if variable environmental factors, such as sunlight/shade, relative humidity, temperature and dew formation (Theiler, 1969), and photoperiod (Rechav, 1981) affected larval survival and/or activity.

The ratio of relative larval abundance at 08h00, 14h00 and 20h00 within gully and open sites in 1981 and 1982 was 1 : 9 : 16 and 1 : 4 : 14 respectively (Table 7.1). This indicated an increase in numbers from morning to evening. The decrease in variation from morning to evening as indicated by the decreasing CV values would be an expected result due to an increased catch size. One would also expect a greater variation in relative abundance in open sites compared to gully sites if larval occurrence on vegetational surfaces was affected by climatic extremity. The descriptive statistics used in Table 6 do not allow for the consideration of several important variables and possible interaction between these variables. For this reason analysis of variance (ANOVA) was conducted.

4.3.3 Site/time/monthly and yearly comparisons using analysis of variance (ANOVA)

The non-significant interaction shown in Table 7.2.1 between sampling time and years, despite altered sampling time orders in 1981 and 1982, indicates that catch size was not significantly affected by sampling time order. Table 7.2.1 shows that there was a significant difference ($P<.01$) in relative abundance at daily sampling times.

Further analysis of this result summarized in Table 7.2.2 indicates that relative abundance at 08h00 and 14h00 was significantly lower than that at 20h00 but that there was no significant difference between catches made at 08h00 and 14h00. The relatively high number of larvae sampled at 20h00 compared with 08h00 and 14h00 is illustrated in Graphs 7.1, 7.2 and 7.3 of the untransformed data. These results indicate that the free-living larvae of R.glabroscutatum are nocturnally active.

The retransformed means with 95% confidence levels of populations sampled at 08h00, 14h00 and 20h00 were 0.9 (+5.6, 0.1); 1.9 (+13.6, 0.3); and 8.8 (+42.8, 1.8) respectively. ANOVA indicated no significant difference in relative abundance between open and gully sites, 1981 and 1982 and months of high relative abundance (Periods P_2 in Table 6) within years 1981 and 1982. Interaction between paired combinations of these factors was not significant.

The result of the comparison between open and gully sites indicated that despite the greater variation in relative abundance in the open area, R.glabroscutatum was still able to survive in this more climatically extreme area.

Hoofmarks, faeces, grazed vegetation and sitings of goat and antelope indicated a high potential host density in open and gully areas. It is probable that the successful occupation by free-living larvae of the relatively small open and gully areas would increase the chances of host encounter considerably.

The comparison in relative larval abundance between 1981 and 1982 indicated that repeated sampling in the same area had not reduced numbers significantly. This observation was further supported by the non-significant result of the paired t-test (Table 7.2.3) which compared the relative abundance at gully and open sites with respective corrected* random controls. Two factors that may account for the failure of repeated dragging to significantly reduce relative abundance were low dragging efficiency and tick immigration. Drag efficiency would have to be very low and larval populations very high to produce no significant reduction in relative abundance through time. This explanation is unlikely considering that 57 drags over the same area were conducted and catch results indicated low larval densities.

With the evidence of high potential host density in open and gully areas, the immigration of females attached to host animals into the sample area would appear a more likely explanation. Recolonisation in the short term may also have been possible, for despite the evidence of limited horizontal migration in free-living tick larvae (Rechav, 1979), only short horizontal movements would have been sufficient to recolonise the 1m wide drag area.

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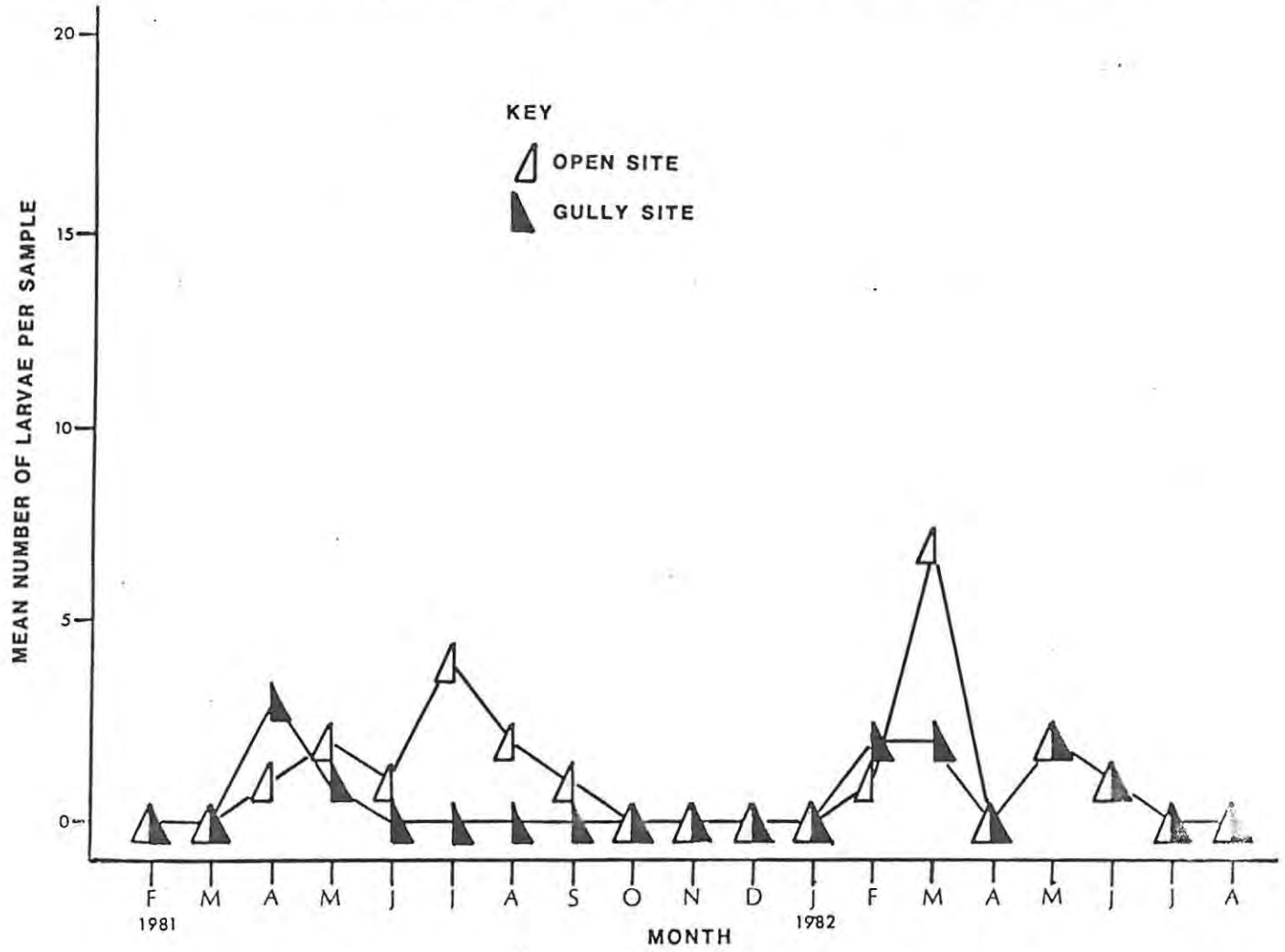
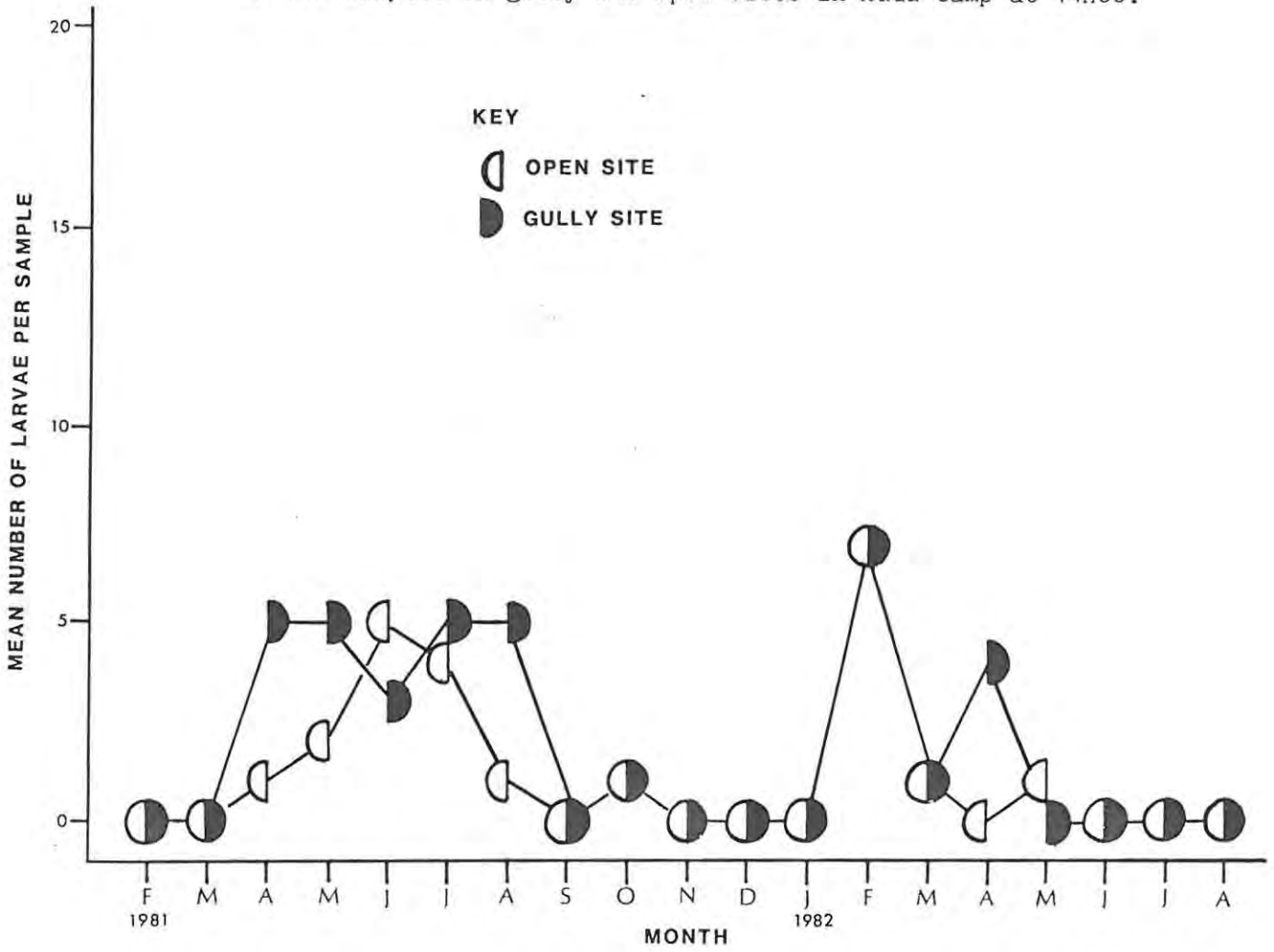
* Explanation in Table 6

GRAPH 7.1 A comparison of the mean number of R.glabroscutatum larvae sampled in gully and open sites in Kudu camp at 08h00.



GRAPH 7.2 A comparison of the mean number of R.glabroscutatum larvae sampled in gully and open sites in Kudu camp at 14h00.



GRAPH 7.3 A comparison of the mean number of R.glabroscutatum larvae sampled in gully and open sites in Kudu camp at 20h00.

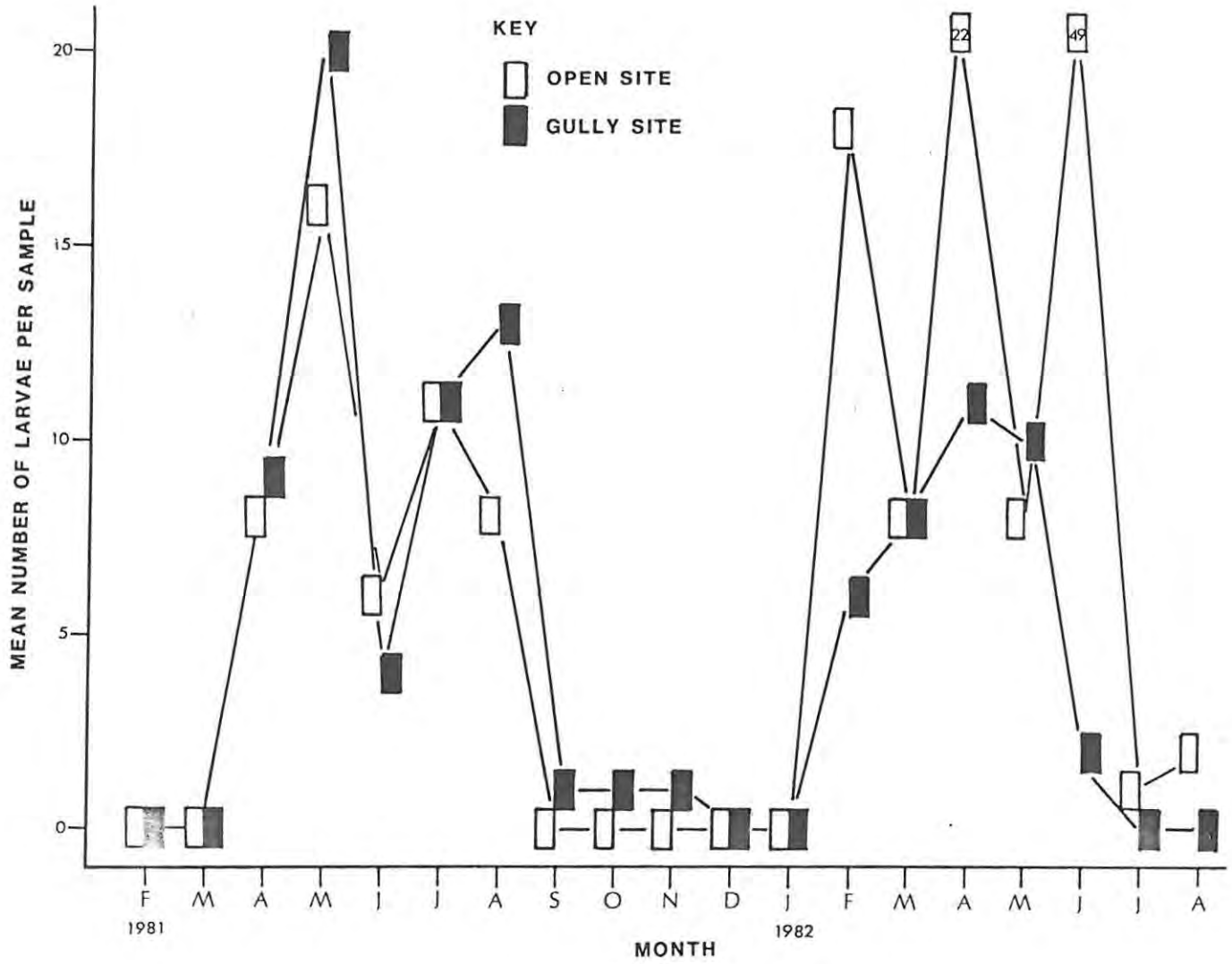


TABLE 7 The statistical analysis of information on the relative abundance of free-living larvae of R.glabroscutatum presented in Table 6.

7.1 Ratio statistics

Site/Time	n	Σ	$n/14$	$(n/14 \times \Sigma) = L$	$L/\frac{G17}{025} = R$
G 08	14	17	1	17	1
G 14	24	85	1.71	145.7	8.6
G 20	19	196	1.36	266.0	15.7
O 08	14	25	1	25.0	1
O 14	24	57	1.71	97.7	3.9
O 20	19	258	1.36	350.1	14.0

7.2 Analysis of variance △

7.2.1 Analysis of variance (ANOVA)

Source of variation	DF	SS	MS	F
site[1] (s)	1	0.011	0.011	0.1 ns
time[2] (t)	2	5.437	2.719	30.6 **
year[3] (y)	1	0.015	0.015	0.2 ns
months[4] (m) in (y)	8	0.800	0.100	0.9 ns
s x t	2	0.198	0.099	1.1 ns
s x y	1	0.032	0.032	0.4 ns
t x y	2	0.376	0.188	2.1 ns
s x m (y)	8	0.395	0.049	0.6 ns
t x m (y)	16	1.843	0.115	1.3 ns
error	18	1.598	0.089	
Total	59	10.705		

$F_{.01}[2,18] = 6.2$

7.2.2 The Student-Newman-Keuls multi-comparison procedure applied to relative larval abundance at 08h00, 14h00 and 20h00.

relative abundance at	N	$\bar{x}$
08h00	20	0.2809 ($\bar{x}1$)
14h00	20	0.4587 ($\bar{x}2$)
20h00	20	0.9895 ($\bar{x}3$)

$$SE = \sqrt{\frac{.0888}{20}} = 0.0667$$

Comparison	Difference	SE	q	p	$Q_{\alpha .01}$ (df = 18)	Conclusion
B vs A	$\bar{x}_B - \bar{x}_A$					
20h00 vs 08h00	0.7086	0.0667	10.64	3	4.70	Reject H_o : $\mu_3 = \mu_1$
20h00 vs 14h00	0.5308	0.0667	7.97	2	4.07	Reject H_o : $\mu_3 = \mu_2$
14h00 vs 08h00	0.1778	0.0667	2.67	2	4.07	Accept H_o : $\mu_2 = \mu_1$

Overall Conclusion $\mu_1 = \mu_2 \neq \mu_3$

95% Confidence limits for $\bar{x}_1$, $\bar{x}_2$ and $\bar{x}_3$

logs of (A + 1)	antilog
$\bar{x}_1$ = 0.2809 $\pm$ .54135	$\bar{x}_1$ = 0.91 $^{+\ 5.64}_{0.14}$
$\bar{x}_2$ = 0.4587 $\pm$ .70505	$\bar{x}_2$ = 1.88 $^{+\ 13.58}_{0.26}$
$\bar{x}_3$ = 0.9895 $\pm$ .65263	$\bar{x}_3$ = 8.76 $^{+\ 42.77}_{1.81}$

7.2.3 Paired t-test (n = 14).

site/time	vs	controls	t value
G 14	vs	$GC^{\square}$	-2.241 ns
O 14	vs	$OC^{\square}$	-1.008 ns

KEY

7.1 Ratio statisics

G = gully area
O = open area
08,14,20 = 08h00,14h00,20h00
n = number of samples
Σ = number of individuals per sample number
R = within site ratio of relative abundance

7.2.1 ANOVA

$\triangle$ = a log (x+1) transformation was performed on data (explanation in text)
DF = degrees of freedom
SS = sum of squares
MS = mean square
F = F ratio
= groups MS / error MS
1 = open/gully area
2 = daily sampling hours (08h00,14h00 and 20h00)
3 = year 1981/1982
4 = months April to August (1981) and February to June (1982)
(period P2 in Table 6)
x = interaction between sources of variation
* = significant at .05 level
** = significant at .01 level
ns = not significant

7.2.2 The Student-Newman-Keuls multicomparison test

q = derived value in test
= $\bar{x}_B - \bar{x}_A / SE$
SE = standard error
p = number of means in the range of means being tested
Q = critical value of the q distribution
α = level of significance
df = degrees of freedom

7.2.3 Paired t test

o = corrected control values (explanation in Table 6)

4.3.4 Evidence of larval adaptation within the Kudu camp ecosystem

The survival of free-living ticks is dependent on climatic factors and host location (Sutherst et al., 1978). Kudu camp normally has a low annual rainfall (300-350mm) and high maximum temperatures (up to 40°C). To enhance survival in such an environment one could expect the following adaptations :

(i) Resistance to desiccation

The non-significant difference in relative abundance of ticks in the warmer open sites compared to the cooler gully sites and occurrence of R.glabroscutatum in low rainfall areas of the eastern Cape (Section 6) indicates that this species may be resistant to desiccation. Although there is no experimental evidence that R.glabroscutatum larvae are resistant to desiccation such evidence is available for the free-living larvae of A.hebraeum. Londt (1970) using survival times at the 50% quartile at 70% RH and 26°C showed that the free-living larvae of A.hebraeum were resistant to desiccation. The larvae of A.hebraeum were rarely sampled in the warmer open sites but were abundant in the cooler gully and bush sites in Kudu camp as opposed to R.glabroscutatum larvae which were present in open sites. These observations suggest that the free-living larvae of R.glabroscutatum may well be more resistant to desiccation than the free-living larvae of A.hebraeum.

(ii) Mechanisms to maintain water balance

Theiler (1969) suggested that dew may be an important source of water for free-living larvae. Dew formation was highest during autumn and winter at Kudu camp and occurred principally in open and gully areas (Section 3).

It has been demonstrated by Londt & Whitehead (1972) that A.hebraeum larvae drink free water. Londt (1970) conducted experiments demonstrating that Rhipicephalus appendiculatus could maintain its weight at 26°C and 70% RH. At 26°C and 90% RH this species could gain weight (probably via the uptake of water vapour through the cuticle). Londt postulated that in field conditions water lost during midday may be regained during times of favourable relative humidity and temperature. Mean seasonal relative humidity recorded at Kudu camp at 08h00 and 20h00 was ± 80% and ± 70% respectively while mean temperatures at these times were below 21°C. Therefore should R.glabroscutatum have the ability to take up water, the conditions of dew formation, relative humidity and temperature fulfill the requirements of the postulates of Theiler (1969) and Londt (1970).

(iii) Behavioural/activity patterns to avoid climatic extremes and increase the chances of host encounter.

A nocturnal activity cycle has the advantage that relative humidity is high, temperature stable and consequently climatic stress low. Nocturnal activity would increase the chance of host encounter considerably if potential hosts are active at night.

4.4 CONCLUSION

By adopting a nocturnal and seasonal activity pattern, and occupying the gully and more climatically extreme open sites at Kudu camp the free-living larvae of R.glabroscutatum have increased the chance of survival and host encounter. Results suggest that the free-living larvae of R.glabroscutatum are well adapted to this climatically extreme region.

5. PARASITIC LIFE STAGES OF R.GLABROSCUTATUM ON ANGORA AND BOER GOATS

5.1 GENERAL INFORMATION ON STOCK AND FARM MANAGEMENT

A breakdown of the goat population on the farm is given in Table 8.

TABLE 8 The goat population at Brakhill farm during 1981.

Goat Breed	Angora goats	Boer goats
Breeding ewes	1200	450
Breeding rams	100	20
Non breeding stock	1700	130
TOTAL	3000	600
Ratio	5	1
Approximate % annual loss	6	8

Stocking density was ±1 goat/ha. In the rotational grazing system used Angora goats succeeded Boer goats every 3 months. The greater percentage loss of Boer goats may therefore have been due to the higher risk of first occupation. In certain camps such as Kudu camp, goat mortality was as high as 15%.

The major problems of goats were attributed to Cowdria ruminantium infection (heartwater), transmitted by the bont tick Amblyomma hebraeum, and lameness.

Chemical control of ticks was used extensively at Brakhill.

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Goats were plunge dipped every week in summer and every 2 to 3 weeks in winter. Tetracyclines were administered intramuscularly at 2-weekly intervals to goats in the camps most affected by heartwater.

5.2 METHODS AND MATERIALS

5.2.1 Experimental stock

Camps 13 and 14 within Kudu camp were stocked with 20 tagged goats. These consisted of 10 Angora and 10 Boer goats selected randomly from groups of wethers. The area occupied by the goats represented 57% of Kudu camp and 5% of the total farm area.

At weekly intervals from February 1981 until March 1982 between 09h00 and 14h00 ticks were removed from the experimental animals. The experimental stock was not subjected to chemical control of external parasites. Table 9 summarizes information concerning the experimental stock.

TABLE 9 Details of the experimental stock maintained in Kudu camp.

	Angora goats	Boer goats
Tag number	1 to 10	1 to 10
Sex	Wethers	Wethers
Age (yrs) at 15.09.81	3	2
Mean mass (Kg) at 01.03.82	50.6 $\pm$ 7.28	50.5 $\pm$ 6.08

5.2.2 Sampling procedure

5 separate samples were taken from each goat. These consisted of 4 samples taken from the feet and 1 body sample.

The body search included the following areas:

i) muzzle
ii) ear
iii) upper leg (above the knee on front legs and above the hock on hind legs)
iv) ventral trunk
v) genitalia
vi) anal region
vii) perianal region
viii) tail

The feet were examined below the fetlock. Figures 1 and 2 show the region of the lower foot searched and indicate the upper limit of this area.

Goats were sampled in the following manner. Animals were placed on their rumps with a worker holding the head well above ground level. A second and third worker sampled the left and right feet respectively. The search, covering the area defined above, was of unlimited duration and consisted of covering the area once and removing all visible ticks using forceps. After the completion of foot samples both workers then conducted a body search. Ticks from each foot and the body were placed in bottles containing 70% alcohol. Throughout the study I sampled the left feet of the experimental goats while my assistants sampled the right feet.

FIGURE1 An anterior view of a goat hoof.

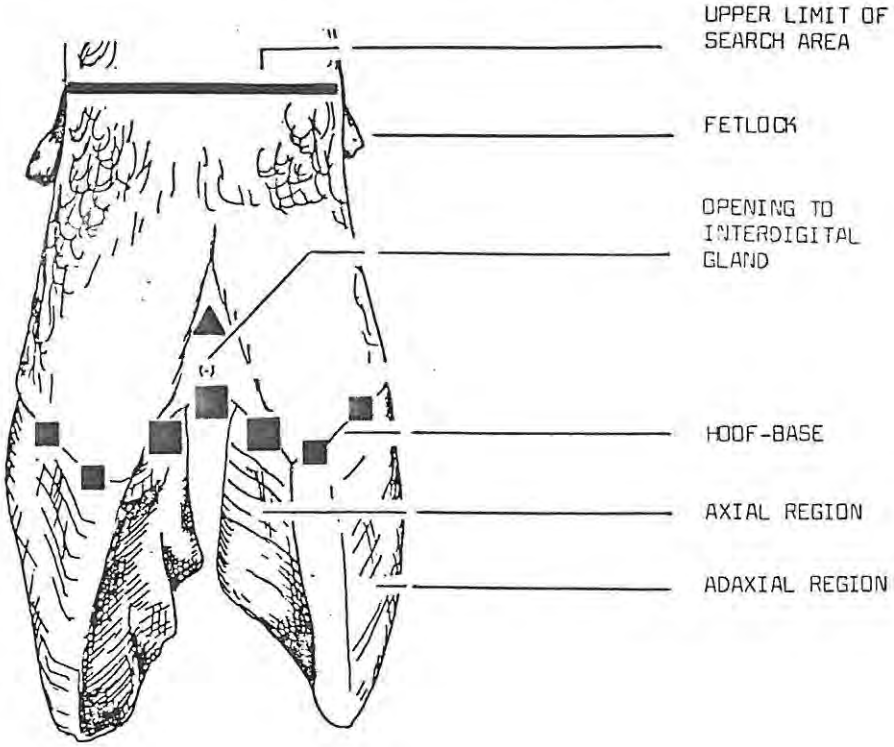
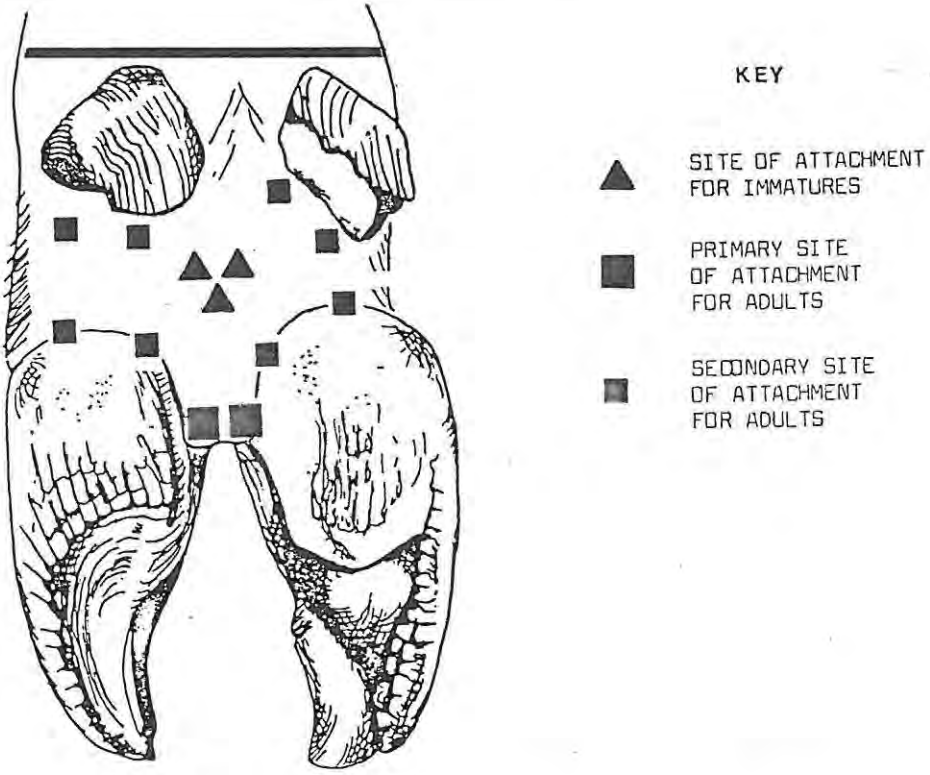


FIGURE2 A posterior view of a goat hoof.



The ticks were transported to the Tick Research Unit, Grahamstown, where they were counted and identified using a stereoscopic microscope. R.glabroscutatum females were judged semi-engorged if distension relative to unfed reference specimens bred at the Tick Research Unit was observed. Counts of semi-engorged females were done from August 1981 onwards in order to compare the proportion of semi-engorged females present on Angora and Boer goats.

5.2.3 Analysis of data

Only counts of adult numbers were statistically analysed because large standard deviations in counts of parasitic immatures suggested the possible inefficiency of the live sampling method for small life stages (Table 10, column 9).

Counts of larvae and nymphae were combined into a single count of immatures (Table 10, Graph 8.3). This procedure was considered justifiable because R.glabroscutatum is a 2 host species, i.e. the larval stage feeds, moults and becomes a feeding nymph on the same host without dropping off (Du Toit, 1941; Rechav & Knight, 1981).

Analysis of variance was conducted on adult tick counts made from August to December 1981, the period of maximum adult abundance (Table 10). Variables considered in the analysis were tick sex, month of occurrence, foot count and goat breed (Tables11 & 12). A log (x + 1) transformation was performed due to the inequality of variances and, because small and zero numbers of items were recorded.

5.3 RESULTS

5.3.1 Sites of attachment

Of the few ticks obtained from the body, adults were located on the ventral trunk while nymphs and larvae were located on the muzzle and ventral trunk. On the feet R.glabroscutatum adults were found predominantly in the anterior axial region of the hoof-base and around the interdigital gland. Solitary adults were found attached in the posterior foot region immediately below the fetlock and in the adaxial region of the hoof-base (Figures 1 & 2). Nymphs and larvae were found on the feet in the anterior axial region just above the interdigital gland and in the posterior foot region between the fetlock and hoof-base (Figures 1 & 2).

5.3.2 Adult tick numbers

Counts were made from February 1981 until March 1982 and included 246 observations on the 10 experimental Angora goats and 240 observations on the 10 experimental Boer goats. Tick numbers on the feet accounted for over 99% of the total number of ticks counted over this period.

The mean number of female and male ticks counted on the feet of the goats from February 1981 to March 1982 was 6.6 and 5.8 on Angora goats compared with a mean number of 3.9 and 3.3 on Boer goats (Table 10, columns 1 and 4). The mean number of males and females was markedly higher from August until December 1981, the period of maximum adult abundance (Graphs 8.1 and 8.2). There was a significant difference ($P < .01$) in adult numbers on Angora goat feet compared with Boer goat feet over this period (Table 12.1, row 1).

Table 12.1, row 2 shows that there was a significant difference in adult numbers between feet ($P < .01$) during the period August to December 1981. Table 12.2.1 gives the deviation of mean adult numbers on each foot, from the grand mean of 2.4 for all feet. For both left and right hand side workers adult counts were higher on the hind feet where mean numbers of 2.7 and 2.5 were recorded respectively than on the front feet. The right side worker counted more ticks on the front feet (mean 2.4) than the left side worker (mean 2.0). The mean number of adults for both front feet counts was 2.2 and the mean number of adults for both hind feet counts was 2.6 (Table 12.2.1).

When the data used in ANOVA analysis (Table 11) was recoded so as to compare front feet counts with hind feet counts a significant difference ($P < .01$) between adult numbers on front vs hind feet was obtained (Table 12.2.2).

5.3.3 Female : male sex ratios

The monthly female : male ratios showed that male numbers were usually lower than female numbers (Table 10, columns 6 & 7). An exception to this trend was during the period July until October 1981 when male numbers were higher. During the period of maximum adult abundance from August until December 1981, male numbers were higher until October while female numbers were higher in November and December. However, there was no significant difference between the sexes during the period August until December 1981. The significant interaction ($P < .01$) between tick sex and month (Table 12.1, row 10) was therefore due to marked increases and decreases in the sexes during the period of maximum adult abundance.

5.3.4 Numbers of semi-engorged females

From August 1981 until March 1982 the 'average' percentage of semi-engorged females was 52% on Boer goats and 40% on Angora goats (Table 10, column 3). This indicated that the proportion of females attaching and taking an initial blood meal was higher on Boer goats compared to ticks on Angora goats.

5.3.5 Parasitic immatures

During 1981 parasitic immatures had 2 periods of greatest abundance on goats (Graph 8.3). In the first period in April and May (the end of autumn and beginning of winter) numbers were lower than in the second longer period of occurrence from July to October (the end of winter to the end of spring.)

It is unlikely that these 2 periods of abundance represented 2 distinct populations since the source population of free-living larvae was clearly indicated as a single bimodal population (Graph 6.1).

The trend of higher numbers of adult ticks on Angora goats compared with Boer goats was also apparent for the immatures although immature counts were considered less reliable. Due to the sampling method, the small number of immatures (compared to adult numbers) did not necessarily relate accurately to the actual numbers of immatures on goats.

Graph 8.3 shows that the relative abundance of free-living larvae was synchronous with parasitic counts on Angora and Boer goats.

Arguments supporting the relationship between low rainfall and the abundance of free-living larvae (4.3.1) are therefore applicable to parasitic immatures, although probably of less importance due to the effect of the host 'environment' on parasitic stages.

5.3.6 Seasonal occurrence

Free-living life stages, parasitic immatures and parasitic adults were all present for relatively long periods in 1981 (Graph 9). Free-living larvae were present from April to August (late autumn, winter and early spring) and parasitic immatures from April to October (late autumn, winter and the whole of spring). Peaks in abundance for free-living and parasitic immatures were in May and August (early winter and early spring). Adult numbers began to increase in August reaching maximum abundance in October and November at the end of spring and beginning of summer. There was no significant difference in adult numbers recorded on goat feet between October and November although adult numbers in these months were significantly higher ($P < .01$) than in August, September and December (Table 12.3)

5.3.7 Foot abscesses

Graph 9 shows that the percentage of experimental goats with foot abscesses followed a similar increase to that in adult tick numbers. Table 13 presents information on foot abscesses recorded from the experimental goats from February 1981 until March 1982. There were 35 counts of foot abscesses on 8 Angora goats while 20 counts of foot abscess were made on 7 Boer goats.

TABLE 10 Monthly numbers of R. glabroscutatum on Angora and Boer goats with associated descriptive statistics (February 1981 to March 1982).

				FEMALE TICKS ON FEET					MALE TICKS ON FEET			SEX RATIO	IMMATURES ON FEET					RECORD OF FOOT ABSCESSES			ΣBODY COUNTS			
	MONTH	BREED	σ^n	Σ	$\bar{x}$	SD	Σ^e	$\%^e$	Σ	$\bar{x}$	SD	♀ : ♂	Σ N	Σ L	Σ N+L	$\bar{x}$	SD	ng	%g	%g A+B	♀	♂	N	L
	Feb	A	19^2	273	14	6.3			108	6	3.2	1 : 0.4	0	0	0	0		0						
	1981	B	20^2	95	5	2.1			36	2	1.5	1 : 0.4	0	0	0	0		0						
	March	A	16^2	41	3	1.8			37	2	2.2	1 : 0.9	0	0	0	0		0						
		B	16^2	18	1	0.9			10	1	0.7	1 : 0.6	0	0	0	0		0						
	April	A	25^3	4	0				3	0		1 : 0.8	20	7	27	1.1	1.4	0						1
		B	28^3	1	0				10	0		1 : 10.0	20	4	24	0.9	0.7	0						1
	May	A	32^4	2	0				1	0		1 : 0.5	83	21	104	3.3	5.9	0					2	
		B	26^4	0	0				0	0			13	1	14	0.5	0.4	0			1		14	2
	June	A	31^4	1	0				4	0		1 : 4.0	0	1	1	0		0			1			
		B	31^4	3	0				3	0		1 : 1.0	2	0	2	0		0						
	July	A	6^1	5	1	0.8			39	7	2.4	1 : 7.8	6	0	6	1.0	2.0	1	17	9				
		B	6^1	11	2	1.3			5	1	1.2	1 : 0.5	3	0	3	0.5	0.5	0	0					
Period of maximum adult abundance	Aug	A	17^3	77	5	2.1	19	25	138	8	4.7	1 : 1.8	105	2	107	6.3	7.8	5	29	15				
		B	17^3	34	2	1.3	12	35	50	3	1.5	1 : 1.5	36	3	39	2.3	2.4	0	0				1	
	Sept	A	15^3	176	12	3.4	81	46	259	17	6.3	1 : 1.5	25	2	27	1.8	2.2	4	27	20		1		
		B	15^3	95	6	2.5	42	44	125	8	4.8	1 : 1.3	29	4	33	2.2	2.6	2	13		1	2	10	
	Oct	A	13^3	345	27	14.8	159	46	362	28	13.5	1 : 1.0	18	2	20	1.5	3.1	3	23	35	1			
		B	13^3	158	12	9.6	105	66	219	17	4.3	1 : 1.4	16	0	16	1.2	2.0	6	46			1	2	
	Nov	A	20^4	468	23	13.2	196	42	316	16	7.5	1 : 0.7	0	0	0	0		6	30	25		1		
		B	20^4	382	19	7.2	167	44	232	12	9.2	1 : 0.6	1	0	1	0		4	20		1			
	Dec	A	9^2	156	17	7.4	71	46	79	9	6.3	1 : 0.5	0	0	0	0		2	22	17	1			
		B	9^2	96	11	6.9	47	49	51	6	5.6	1 : 0.5	0	0	0	0		1	11					
	Jan	A	5^1	11	2	2.3	4	36	8	2	0.9	1 : 0.7	0	0	0	0		3	60	30				
	1982	B	5^1	14	3	0.8	5	36	4	1	0.8	1 : 0.3	0	0	0	0		0	0					
	Feb	A	15^3	33	2	1.2	11	33	66	3	2.8	1 : 2.0	62	29	91	6.1	4.9	0	0	7				
		B	15^3	23	2	1.4	20	87	36	2	1.8	1 : 1.6	44	4	48	3.2	3.0	2	13					
	March	A	23^5	25	1	1.1	11	44	13	1		1 : 0.5	129	53	182	7.9	7.1	0					3	
		B	20^5	13	1	0.7	7	54	3	0		1 : 0.2	29	4	33	1.7	1.9	0						
	$\Sigma/\bar{y}$	A	246	1617	6.6			40	1433	5.8		1 : 0.9	448	117	565	2.3		24			3	2	5	1
		B	240	943	3.9			52	784	3.3		1 : 0.8	193	20	213	0.9		15			3	3	27	3
	column number				1	2		3		4	5	6 7				8	9	10						

KEY (TABLE 10)

A = Angora goat

B = Boer goat

G^n = number of goats inspected and number of inspections.

Σ = sum/total number of ticks

$\bar{x}$ = mean number of ticks per goat

SD = Standard deviation of $\bar{x}$

Σ^e = number of semi-engorged females

$\%^e$ = percentage of females semi-engorged

♀ : ♂ = female to male ratio

N = nymphs

L = larvae

ng = number of goats with foot abscesses

%g = percentage of goats with foot abscesses

$\Sigma\Sigma$ = sum of data in columns = grand mean

$\bar{y}$ = mean of data in columns

TABLE 11 Data matrix of numbers of R.glabroscutatum adults recorded on Angora and Boer goat feet (August 1981 to December 1981).

Month		August								September								October								November								December								
Sex		♀				♂				♀				♂				♀				♂				♀				♂				♀				♂				
Foot		RF	RB	LF	LB	RF	RB	LF	LB	RF	RB	LF	LB	RF	RB	LF	LB	RF	RB	LF	LB	RF	RB	LF	LB	RF	RB	LF	LB	RF	RB	LF	LB	RF	RB	LF	LB	RF	RB	LF	LB	
Goat number	1	1	0	0	0	5	1	2	0	4	1	4	3	7	0	8	10	3	1	0	2	10	0	4	1	8	8	5	4	4	11	4	5	4	6	4	4	3	6	4	7	Angora goats
	2	0	1	1	2	0	5	4	4	4	0	1	2	1	1	3	5	5	2	2	1	8	6	5	6	0	1	1	4	1	1	0	2	12	12	3	3	0	9	4	0	
	3	2	1	0	1	1	9	3	3	5	0	3	3	8	0	6	8	5	5	7	11	8	10	9	15	0	1	0	4	4	4	0	5	4	8	6	8	0	6	2	7	
	4	1	1	0	1	3	1	2	4	3	2	4	7	5	3	0	10	21	6	25	18	14	4	4	16	8	6	4	4	3	4	8	4	4	2	4	5	0	1	1	3	
	5	5	2	1	2	7	1	0	3	1	2	3	4	2	5	3	3	12	5	6	16	15	6	1	6	10	2	7	3	5	5	1	1	6	3	5	6	1	0	0	1	
	6	1	4	1	2	4	6	2	5	4	7	2	3	10	11	11	7	2	10	8	11	12	13	4	13	11	8	8	18	7	6	13	16	1	2	2	4	0	0	0	1	
	7	4	2	2	0	4	1	6	2	2	5	3	2	3	2	2	1	14	17	7	7	8	7	2	4	7	4	4	0	5	1	3	2	4	6	3	4	2	3	2	2	
	8	0	4	0	1	0	0	0	1	1	2	1	3	2	3	4	8	9	2	7	3	4	1	7	5	10	6	14	10	7	2	9	8	2	4	2	0	2	4	1	0	
	9	3	1	3	2	3	3	3	7	0	4	1	0	2	5	0	1	13	12	10	13	16	16	7	18	23	19	9	11	4	3	4	9	5	8	3	2	4	1	2	3	
	10	0	3	1	1	0	4	1	3	2	8	2	2	2	12	1	3	4	0	3	7	0	1	8	9	6	1	3	19	2	2	2	24	1	10	1	0	4	2	0	0	
	1	0	0	0	1	1	2	0	1	1	2	1	0	4	1	0	2	11	8	3	0	7	10	3	0	15	1	3	9	4	0	2	4	3	4	10	0	1	2	4	1	Boer goats
	2	0	0	1	1	0	0	1	2	1	2	2	2	2	1	2	4	2	3	2	11	0	4	1	9	2	0	7	4	3	0	7	4	4	4	5	6	2	2	4	2	
	3	0	0	1	0	0	1	0	2	4	1	0	1	4	0	1	5	14	11	6	7	15	15	2	6	9	1	4	2	13	3	7	4	1	6	1	4	0	2	0	2	
	4	0	1	0	2	0	6	2	0	2	1	1	4	6	3	1	5	11	14	12	8	8	11	5	7	5	3	4	1	3	1	2	1	2	1	6	5	1	0	1	0	
	5	0	1	0	2	0	1	0	2	1	0	1	1	0	0	2	4	9	2	4	5	11	9	1	4	4	5	5	8	10	16	7	18	1	7	4	4	1	6	3	1	
	6	0	0	0	0	2	1	0	0	3	1	2	6	0	4	2	1	3	6	1	2	4	3	0	8	6	11	12	11	11	13	4	9	1	2	0	0	0	3	0	0	
	7	1	2	1	0	4	0	0	0	1	7	0	0	2	1	0	1	8	2	3	1	4	0	3	1	0	6	4	17	0	3	1	8	1	1	0	0	0	2	0	0	
	8	0	0	0	3	0	0	0	1	0	1	1	1	0	0	0	1	4	4	1	2	6	7	0	1	6	8	3	5	0	4	1	1	2	3	4	3	0	2	4	4	
	9	0	1	1	0	0	1	0	0	0	0	0	2	0	1	0	2	0	1	0	1	4	2	3	0	4	1	1	2	1	0	1	3	0	1	0	0	0	1	0	1	
	10	3	1	2	1	3	1	2	0	2	2	2	5	1	2	2	7	3	2	2	6	1	2	3	6	4	12	0	9	2	8	0	6	2	3	3	2	1	2	2	1	

TABLE 12 Statistical analysis of adult tick counts from Angora and Boer goat feet (raw data is shown in Table 11).

12.1 Analysis of variance (ANOVA).

Row	Source of variation	DF	SS	MS	F	Significance of F	Further analysis
1	Goat (G)	1	5.605	5.605	61.3 ***	.001	
2	Foot (F)	3	1.235	0.412	4.5 **	.004	12.2
3	Sex (S)	1	0.155	0.155	1.7 ns	.190	
4	Month (M)	4	20.673	5.168	56.6 ***	.001	12.3
	INTERACTION						
5	GxF	3	0.101	0.034	0.4 ns	.999	
6	GxS	1	0.054	0.054	0.6 ns	.999	
7	GxM	4	0.689	0.172	1.9 ns	.110	
8	FxS	3	0.196	0.065	0.7 ns	.999	
9	FxM	12	2.319	0.193	2.1 ns	.014	
10	SxM	4	2.542	0.636	7.0 ***	.001	
11	GxFxS	3	0.076	0.025	0.3 ns	.999	
12	GxFxM	12	0.803	0.067	0.7 ns	.999	
13	GxSxM	4	0.356	0.089	1.0 ns	.999	
14	FxSxM	12	0.230	0.019	0.2 ns	.999	
15	GxFxSxM	12	0.196	0.016	0.2 ns	.999	
	Error	720	65.779	0.091			
	Total	799	101.010	0.126			

KEY

DF = degrees of freedom
SS = sum of squares
MS = mean square
F = F ratio = groups MS / error MS
** = significant at .01 level
*** = significant at .001 level
ns = not significant

12.2 Further analysis of adult tick counts on goat feet.

12.2.1 Log deviation (D) from the grand mean (GM) of adult tick numbers on goat feet.

Sample	N	D	log	mean	corrected mean (mean - 1)
RF	200	0.00	0.53	3.4	2.4
RB	200	0.01	0.54	3.5	2.5
LF	200	-0.06	0.47	3.0	2.0
LB	200	0.04	0.57	3.7	2.7
RF + LF	400	-0.03	0.50	3.2	2.2
RB + LB	400	0.03	0.56	3.6	2.6

GM =0.53

corrected = 3.3884 - 1 = 2.4

KEY

RF = right front foot

RB = right back foot

LF = left front foot

LB = left back foot

12.2.2 ANOVA 12.1 repeated with recode (RF + LF) vs (RB + LB).

Source of variation	DF	SS	MS	F	Significance of F
FOOT (RF+LF) vs (RB+LB)	1	0.682	0.682	7.4 **	0.007
Error	760	69.810	0.092		

12.3 The Student-Newman-Keuls multi-comparison procedure applied to adult abundance on goat feet from August 1981 to December 1981.

Month	N	$\bar{x}$
August	160	0.30 $\bar{x}_1$
September	160	0.47 $\bar{x}_3$
October	160	0.74 $\bar{x}_5$
November	160	0.69 $\bar{x}_4$
December	160	0.46 $\bar{x}_2$

Standard error $SE = \sqrt{\frac{S^2}{n}}$

$= \sqrt{\frac{.091}{160}}$

$= .0238$

Comparison	Difference	SE	q	p	Q $\alpha = 0.001$ df = 720	Conclusion
5 vs 1	0.44	2.0238	18.5	5	5.5	Reject H_o: $/u_5 = /u_1$
5 vs 2	0.28		11.8	4	5.3	Reject H_o: $/u_5 = /u_2$
5 vs 3	0.27		11.3	3	5.1	Reject H_o: $/u_5 = /u_3$
5 vs 4	0.05		2.1	2	4.7	Accept H_o: $/u_5 = /u_4$
4 vs 1	0.39		16.4	4	5.3	Reject H_o: $/u_4 = /u_1$
4 vs 2	0.23		9.7	3	5.1	Reject H_o: $/u_4 = /u_2$
4 vs 3	0.22		9.2	2	4.7	Reject H_o: $/u_4 = /u_3$
3 vs 1	0.17		7.1	3	5.1	Reject H_o: $/u_3 = /u_1$
3 vs 2	0.01		0.4	2	4.7	Accept H_o: $/u_3 = /u_2$
2 vs 1	0.16		6.7	2	4.7	Reject H_o: $/u_2 = /u_1$

Overall conclusion $/u_1 \neq /u_2 = /u_3 \neq /u_4 = /u_5$

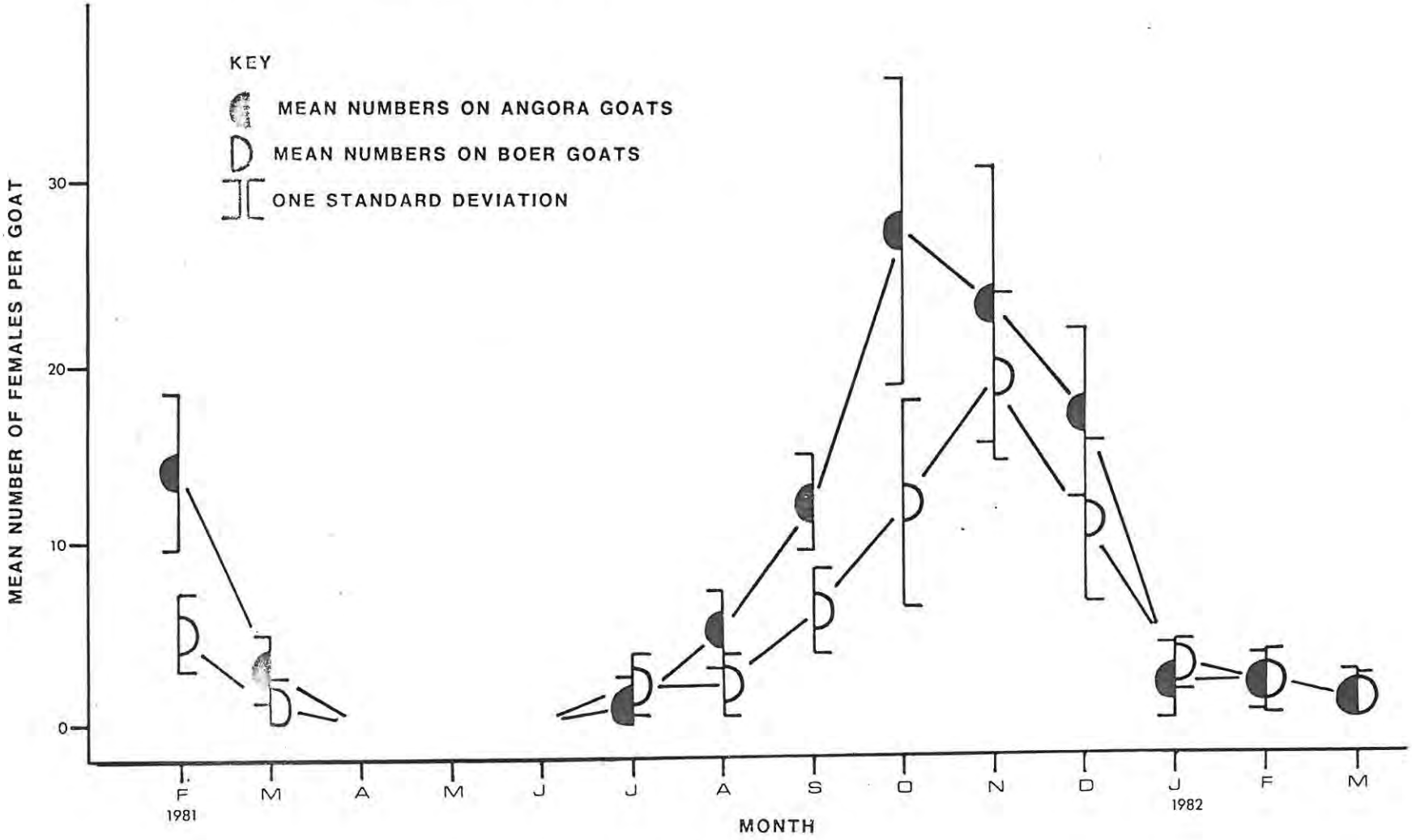
TABLE 13 Records of foot abscesses in 10 Angora and 10 Boer goats from February 1981 until March 1982.

Sample	Number of abscesses (A)		Sum	Difference
	Angora goats	Boer goats		
Front feet (F)	13	2	15	25
Back feet (B)	22	18	40	
Left feet (L)	23	13	36	17
Right feet (R)	12	7	19	
Total feet with abscesses	35	20	55	15
Goats with FA	2	1	3	11
Goats with BA	8	6	14	
Goats with LA	6	7	13	6
Goats with RA	5	2	7	
Total goats with abscess	8	7	15	1

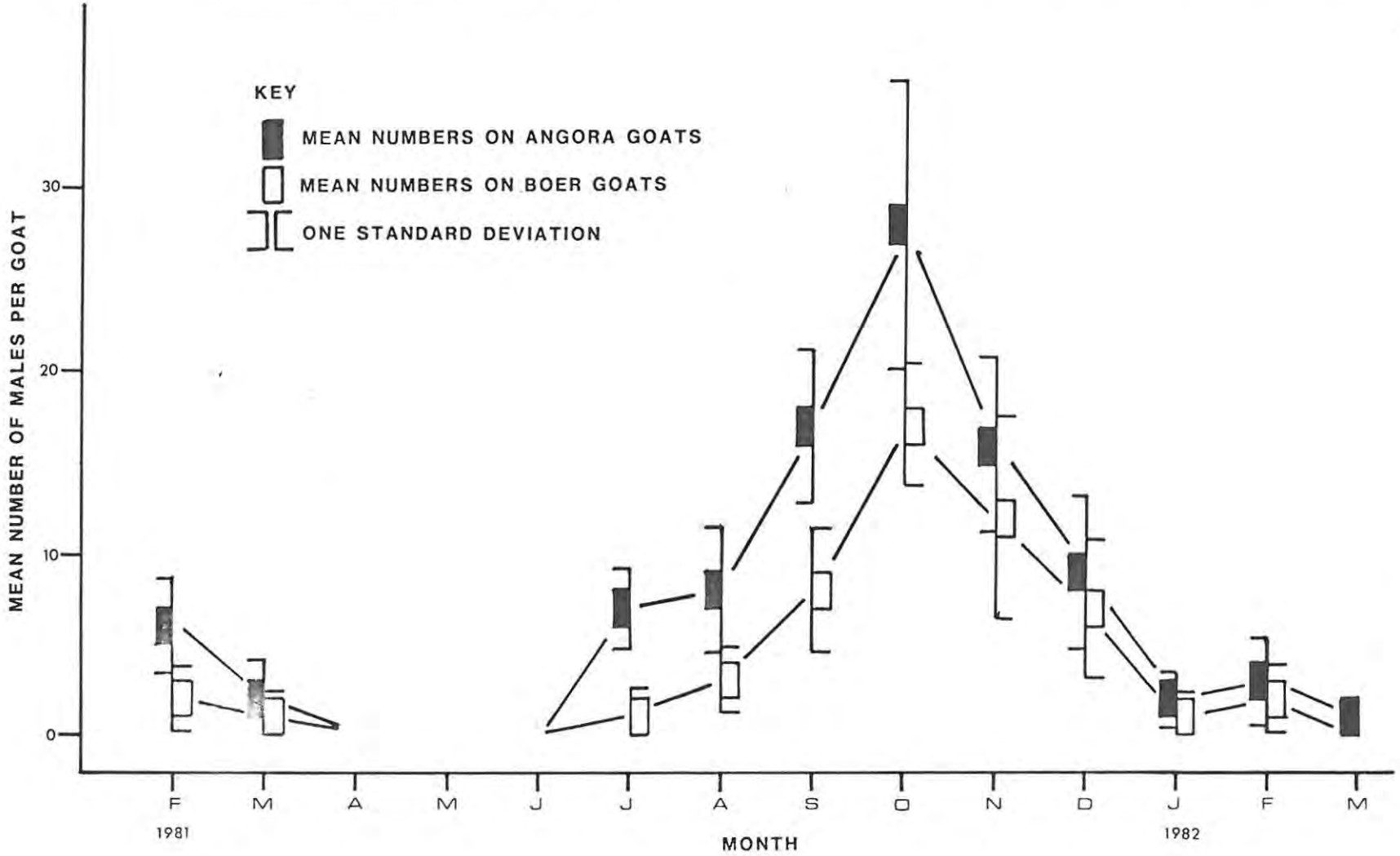
KEY

FA = front foot abscesses
BA = back foot abscesses
LA = left foot abscesses
RA = right foot abscesses

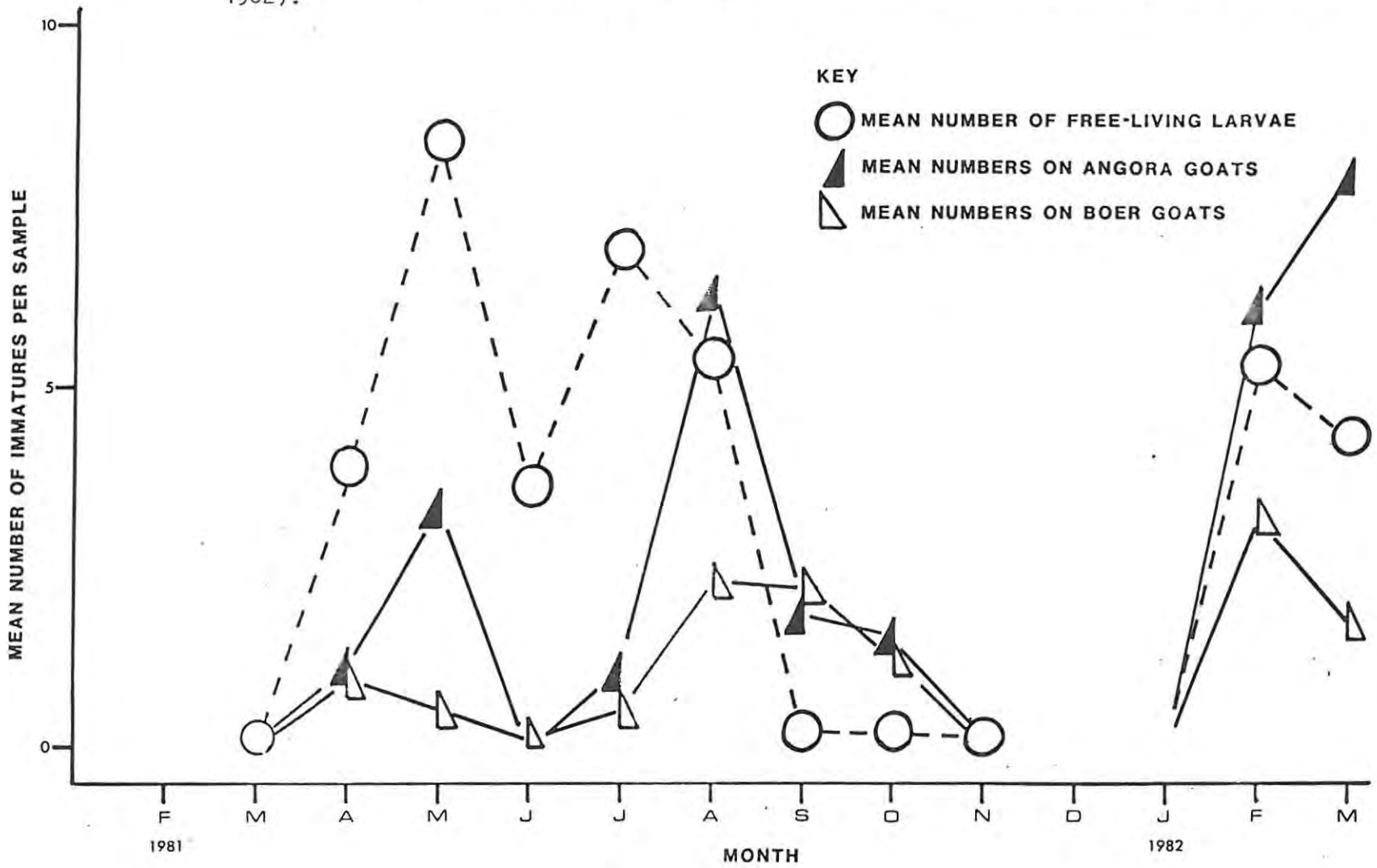
GRAPH 8.1 THE MONTHLY MEAN NUMBER OF *R.GLABROSCUTATUM* FEMALES ON ANGORA AND BOER GOAT FEET FROM FEBRUARY 1981 UNTIL MARCH 1982 .



GRAPH 8.2 THE MONTHLY MEAN NUMBER OF *R.GLABROSCUTATUM* MALES ON ANGORA AND BOER GOAT FEET FROM FEBRUARY 1981 UNTIL MARCH 1982.

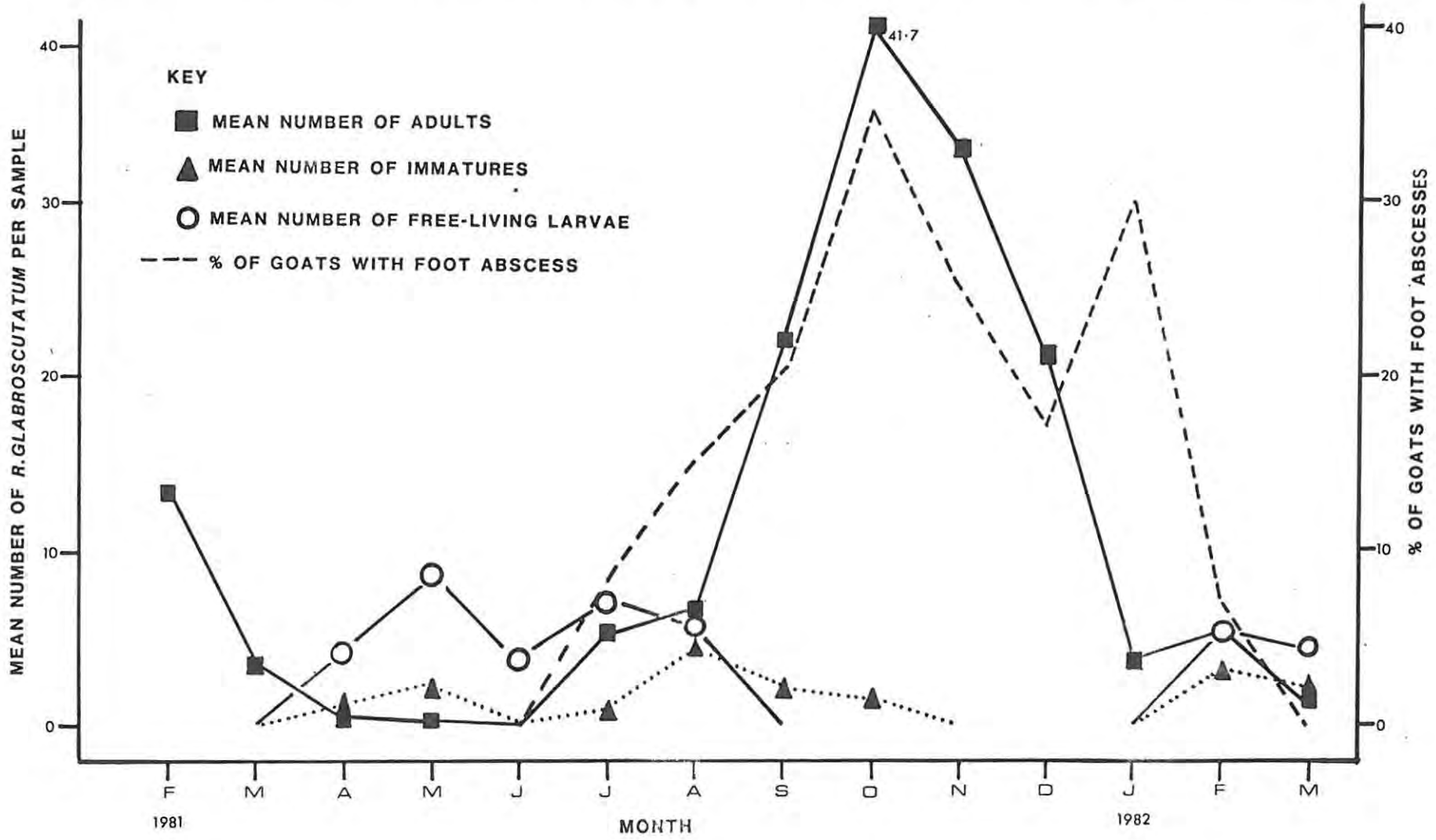


GRAPH 8.3 The monthly mean number of R.glabroscutatum immatures (nymphs and larvae) on Angora and Boer goat feet and free-living larvae sampled from vegetation (February 1981 to March 1982).



GRAPH 9

The mean monthly abundance of free-living larvae and parasitic life stages of R.glabroscutatum and the percentage of foot abscesses recorded monthly on Angora and Boer goat feet (February 1981 to March 1982).



In both goat groups there were more foot abscesses on the hind feet than the front feet (40 vs 15 respectively) and more abscess on left feet than on right side feet (36 vs 19 respectively). Since these counts included some repeated observations of abscesses on the same feet, the number of goats with foot abscesses was considered a better indication of trends.

In the Angora goat group 2 animals had abscesses on the front feet while 8 had abscesses on the hind feet. In the Boer goat group the trend was similar and the numbers affected were 1 and 6 respectively (Table 13). The trend towards more abscesses on the left feet compared to the right feet was reduced when goats with abscesses rather than observations of abscesses *per se* were considered. Differences in the number of left and right side abscesses were then 6 compared to a difference of 11 in the number of front vs hind foot infections (Table 13). The overall trend was that of more foot abscesses on hind feet than on front feet.

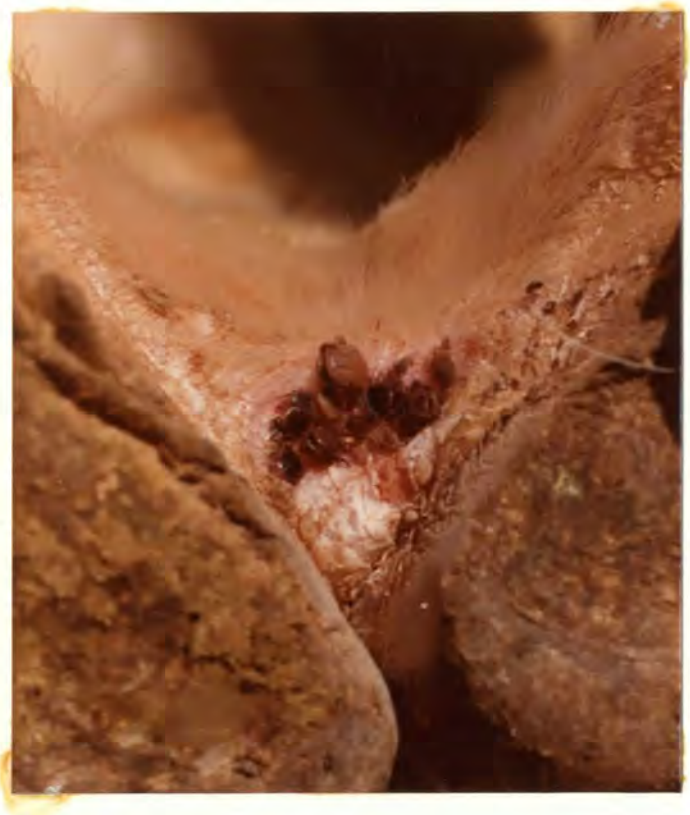
5.4 DISCUSSION

5.4.1 *Sites of attachment*

The numerical predominance of *R.glabroscutatum* adults in the interdigital area on feet (Plate 3) and apparent segregation of adults and immatures on the lower foot invites speculation.It is possible that *R.glabroscutatum* adults were attracted by interdigital secretions since swabs taken from this area were seen to attract ticks in the laboratory.The spatial separation of immatures from adults may have reduced competition for space in the small interdigital area when life stages were not temporarily separated.

It is possible that the occupation by such large numbers of adults of the interdigital region conferred certain advantages to these adults, such as protection from grooming and environmental stability. A study in which tick loads of varying size are monitored in measured interdigital areas with respect to attachment, drop off weight and egg production may provide more evidence for segregation between life stages and the effect of competition on engorgement and egg production.

PLATE 3 Rhipicephalus glabroscutatum adults attached in the interdigital gland area of an Angora goat.



5.4.2 Adult tick numbers

The reason for the larger tick loads recorded on Angora compared with Boer goat feet and hind compared with front feet within both goat groups will require further investigation.

Some possible explanations for the lower tick loads on Boer goat feet are:-

(i) Greater grooming efficiency

There is evidence that Boer goats are highly efficient in removing ticks by grooming (Fielden, pers. comm.,1982).

(ii) A more developed immunological response

There appeared to be no initial immunological response inhibiting attachment or the semi-engorgement of R.glabroscutatum (5.3.4). However, drop off weight and subsequent egg production must provide the final evidence for biological success.

(iii) A physically less suitable site for settlement

Physical differences may include factors such as surface area, skin thickness and follicle density.

(iv) Ecological differences resulting in fewer tick encounters

During observations at Kudu camp, Angora and Boer goats were seen to mix freely and feed together. It would be interesting to compare these observations with those involving a comprehensive study of Angora and Boer goat ecology.

Some possible explanations for the higher tick loads on hind feet in both Angora and Boer goat groups are:-

(i) Worker bias

Tick recovery from hosts using a destructive sampling method such as that of Horak, Meltzer & De Vos (1982) which is independent of visual searching on the animal would be an objective means of comparison.

(ii) Grooming efficiency

If grooming efficiency was greater on front feet due to easier access, higher tick loads on the hind feet would have resulted.

(iii) The manner of host location

If adults were present in relatively low numbers per unit area and the majority of host encounters occurred during goat movement it was possible that a time lag between host perception and host location resulted in higher numbers on the back feet.

5.4.3 Female : male sex ratios

There appears to be no clear explanation for the lower total number of male ticks compared with females (although for practical purposes the ratio was 1 : 1). R.glabroscutatum males were smaller than females and were represented by some very small specimens. It may be argued that inspections were biased in favour of the larger females. However, the vast majority of R.glabroscutatum adults were detected in the small hairless interdigital area, a site easily inspected. In addition more males than females were counted during August, September and October than during November and December 1981. It is possible that solitary males on body areas with dense hair were overlooked.

5.4.4 Seasonal occurrence

The occurrence of a single peak of adults in 1981 indicated that R.glabroscutatum had a single generation per annum. This was supported by the evidence of a single population of free-living larvae during 1981 and 1982.

The 'natural' life cycle was therefore considerably longer than the laboratory life cycle of 84 days determined by Rechav & Knight (1981), who used Himalayan rabbits as hosts for immatures and Guernsey calves as hosts for adult ticks.

The occurrence of maximum adult numbers in October and November (late spring and early summer) at Kudu camp was in partial agreement with the findings of Stampa (1963) and Rechav & Knight (1981).Stampa stated that R.glabroscutatum adults were found on Angora goats during the 'whole summer' (November, December and January) in drier areas of the Karoo while Rechav & Knight claimed that adults were abundant during early summer (November) only, in localized areas of the south eastern Cape. Knight & Rechav (1978) working in the Fish River area obtained R.glabroscutatum adults "in high numbers on kudu from September to January with a peak in November". Results therefore indicate that in the eastern Cape Province, seasonal parasitic activity for adults ranged from early spring (August) until the end of summer (January), with November (early summer) commonly being a month in which high adult numbers were encountered.

Rechav (1980) suggested that the adoption of 1 generation per annum was a method whereby R.glabroscutatum was able to escape hot and dry conditions. At Kudu camp free-living larvae were most abundant during periods of low rainfall when intermediate to low seasonal temperatures prevailed (4.3.1). Parasitic adults were most abundant at a warmer time of the year when rainfall was relatively high. Clearly then the seasonal occurrence of R.glabroscutatum in Kudu camp did not enable free-living larvae and parasitic adults to avoid hot and dry conditions.

On the contrary, R.glabroscutatum appears to be distributed in areas with a low annual rainfall (Section 6).

I suggest that nocturnal activity of free-living larvae in the cooler months of the year from April to August and a general resistance to desiccation in immatures and adults is the form of the adaptation suiting this species to conditions at Kudu camp.

5.4.5 Foot abscesses

Lameness in goats at Kudu camp was caused by foot abscesses (Plate 4). Van Der Westhysen, Wentzel & Grobler (1981) stated that Fusobacterium necrophorum infection causing foot abscesses in Angora goats, occurs via 'small wounds and cracks in the skin between the hooves or around the coronet'. In addition these authors stated that 'wet conditions cause the skin around the hooves to become tender favouring the occurrence of foot abscess'. Given the sharp increase in adult tick numbers from August onwards and concurrent increase in foot abscesses (Graph 9) it is suggested that lesions caused by tick mouthparts may become infected with Fusobacterium necrophorum and thus lead to the occurrence of foot abscesses.

The site of foot abscesses in goats at Kudu camp was the interdigital area adjacent to the hoof base, the same area where large numbers of R.glabroscutatum adults attached. Because A.hebraeum adults were also found attached at similar sites on the feet at the same time and relatively high rainfall occurred from September until December, R.glabroscutatum adults could not be identified as the sole possible factor promoting foot abscess formation.

PLATE 4 Advanced foot abscess in the interdigital area of an Angora goat.

It is possible that the continual removal of attached ticks produced an unnaturally large number of lesions and consequently unrepresentative counts of foot abscesses. A study of goats with intact tick loads should be made for purposes of comparison.

Both Angora and Boer goats appeared to be susceptible to foot abscesses although results indicated that single observations of foot abscesses were higher in Angora goats than in Boer goats (35 and 20 respectively). This result may be explained by the significantly larger tick loads on Angora goat feet. Similarly the trend for more foot abscesses on hind feet in both goat groups may have been due to the significantly larger number of ticks found on Angora and Boer goat hind feet.

The study of a larger group of goats would supply sufficient information for the statistical analysis of the occurrence of foot abscesses.

Observations of the experimental stock indicated that Boer goats limped badly with minor foot abscesses while Angora goats with severe abscesses often appeared to walk normally. Consequently for purposes of comparison, a group of goats would have to be randomly selected and then inspected.

5.5 CONCLUSION

At Kudu camp immatures and large numbers of adults of R.glabroscutatum exploited Angora and Boer goats extensively while adults were implicated as agents promoting foot abscess formation. With the knowledge of tick seasonality and sites of occurrence on the host the adoption of a planned control programme in the Uitenhage area will in future be possible. The large numbers of ticks on the feet compared with the body suggest that correctly timed foot dipping will effectively control R.glabroscutatum numbers. A similar type of control for A.hebraeum attaching on Angora goat feet was advocated by Stampa (1963).

As a general ecological project this work has generated a number of specific questions concerning the relationship between R.glabroscutatum and goat hosts. These include tick biology (or 'success'), goat immunological responses, grooming efficiency and foot abscess.

It is clear that further research on ticks associated with small stock is urgently required.

6. A REVIEW OF DISTRIBUTION AND HOST RECORDS FOR R.GLABROSCUTATUM IN SOUTH AFRICA

6.1 INTRODUCTION

Because contrasting views on the economic importance of R.glabroscutatum have been expressed (Section 1), a review of distribution and host records was considered essential for a re-evaluation of the pest status of this species.

6.2 METHODS

Locality and host records were obtained from my own research, from the literature and from personal communications (see Acknowledgements and References). Longitudes and latitudes, and approximate altitudes for localities were determined from 1:250 000 topographical maps. If a locality was placed between contours or the locality covered a relatively large area (e.g. Mountain Zebra National Park), altitude was expressed as a range (Table 14). Similarly, rainfall was estimated from isohyets on 1:250 000 rainfall maps based on rainfall figures from 1921 to 1960 inclusive.

The classification of vegetation was according to Acocks (1975). For those localities in boundary situations all possible vegetation types were listed.

6.3 RESULTS

6.3.1 Locality records

Map 3 shows that the majority of records (83%) are located in the south eastern Cape in the zone 31°30' to 33°45'S and 24°21' to 26°43'E.

MAP 3 Distribution records for the 'smooth brown tick' Rhipicephalus glabroscutatum in South Africa.

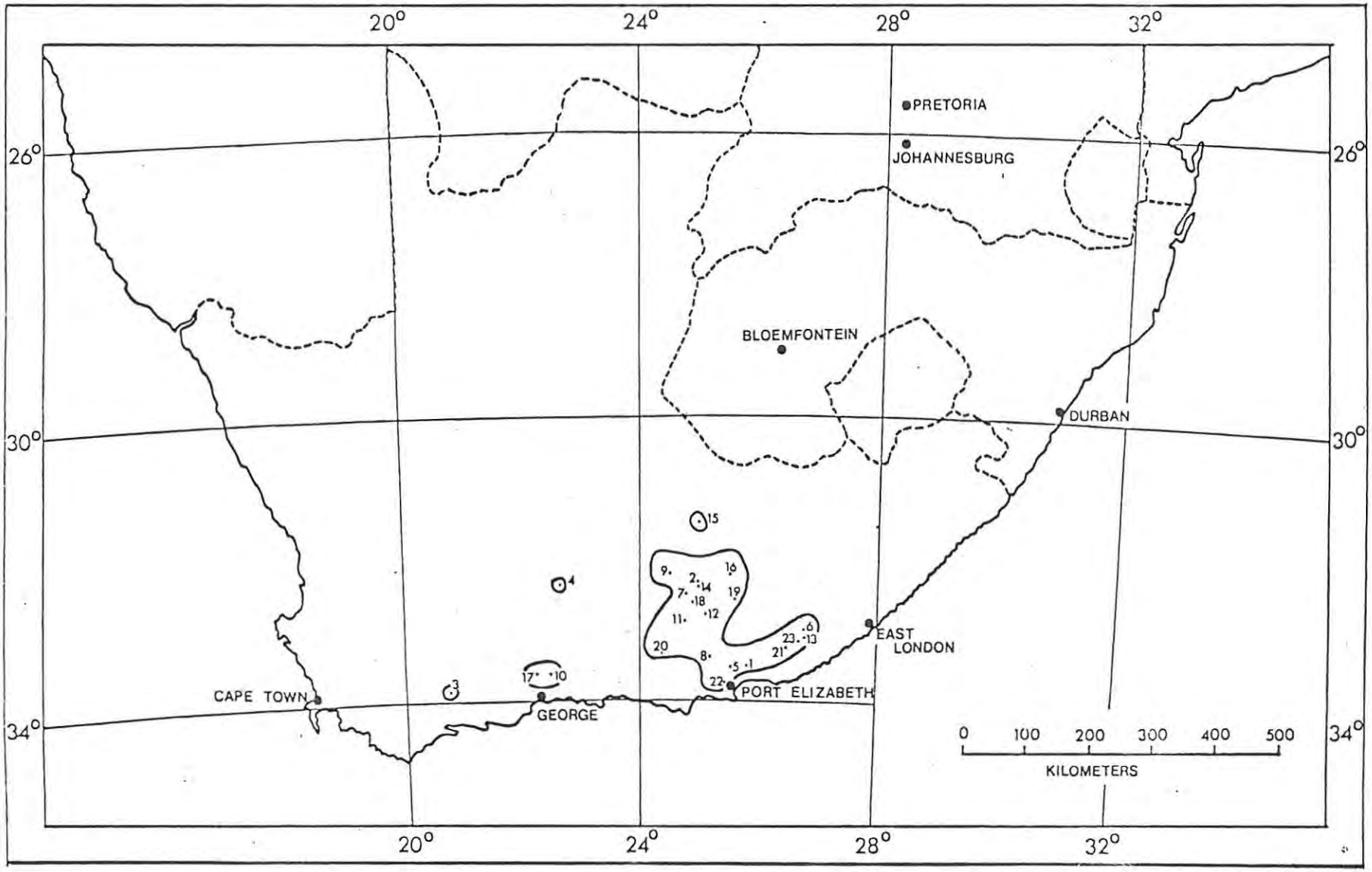


TABLE 14 Locality records for R. glabroscutatum in South Africa

Locality number	Locality name	Longitude South	Latitude East	Alititude (m)	annual Rainfall(mm)	Vegetation* category	Vegetation* type
1	Addo	33°29'	25°45'	200	400	IV	VB
2	Ashbourne	32°24'	25°05'	900	400 - 500	IV, IV A	FU, CL, KB, FK
3	Barrydale	33°54'	20°44'	400	300	IV	KB
4	Beaufort West	32°21'	22°35'	850	200	IV	KB, CL
5	Brakhill	33°33'	25°25'	250	300	IV	VB
6	Bucklands	33°05'	26°43'	300	400	IV	VB
7	Fairview	32°31'	23°59'	800	300	IV, IV A	KB, FU
8	Glenconnor	33°24'	25°10'	200	300 - 400	IV	VB
9	Graaf Reinet	32°15'	24°32'	750	300	IV	SM
10	Homestead	33°38'	22°23'	350	200 - 300	VII A, IV	FS, SM
11	Jansenville	32°56'	24°40'	470	300	IV	N
12	Jouberts Kraal	32°44'	25°06'	700	300	IV	KB
13	Kudu Reserve	33°07'	26°43'	350	400	IV	VB
14	Libertas	32°23'	25°01'	950 - 1000	400 - 500	IV, IV A	FU, CL, KB, FK
15	Middelburg	31°30'	25°00'	1250	300 - 400	IV A	FU,
16	Mnt. Zebra P.	32°16'	25°26'	1400 - 1957	400 - 500	IV A	FU, FK
17	Oudtshoorn	33°36'	22°12'	350	200	IV	KB
18	Pearston	32°35'	25°09'	700	300 - 400	IV A	FU
19	Somerset East	32°44'	25°35'	750	600	III A, IV A	FT, FU
20	Steytlerville	33°20'	24°21'	450	300	IV	SM
21	Table farm	33°15'	26°25'	550	600	IV	VB
22	Uitenhage	33°45'	25°24'	100	400 - 500	IV	VB
23	Ulster farm	33°10'	26°39'	250 - 300	400	IV	VB

* according to Acocks (1975)

Categories

III A = False Bushveld
IV = Karoo & Karroid Bushveld
IV A = False Karoo types
VII A = False Sclerophyllous bush types

Types

III A - FT = False Thornveld of E. Province
IV - VB = Valley Bushveld
KB = Karroid Broken Veld
CL = Central Lower Karoo
SM = Succulent Mountain Scrub
IV A - FU = False Upper Karoo
FK = False Karroid Broken Veld
VII A - FS = Succulent Mountain Scrub and False Macchia

TABLE 15 Host records for R.glabroscutatum in South Africa.

Collector/s	Date	Host	n[x]	Site	Tick life stage ♂	♀	N	L	Locality
Clemow, E	03/11/37 23/11/37	'Angora goats'			P	P			Glen Connor, Uitenhage
Flight, C	06/04/48	Boer goat	1		P	P			Homestead, Oudtshoorn
Thorburn, J	06/07/38 05/09/38	'goats'			P	P			Table farm, Albany
Hobson, B	03/03/39 06/03/39 13/05/39	Merino sheep, Angora goats Boer goats		feet	P P	P P			
Theiler, G	1962	Angora goats* 'sheep' 'goats' Raphicerus campestris (Steenbok) Tragelaphus strepsiceros (Kudu)	1 1		P* P P P	P* P P P			Fairview Aberdeen*, Graaf Reinet, Oudtshoorn, Middelburg, Jansenville, Steytlerville, Uitenhage, Beaufort West, Somerset East, Pearston, Albany, Barrydale (Swellendam).
Schulz, D	28/08/70	Syncerus caffer (Buffalo)	1	body			P		Addo Elephant Park
	28/08/70	Syncerus caffer (Buffalo)	1	body	1				Addo Elephant Park
	31/08/70	Alcelaphus buselaphus caama	1				1		Addo Elephant Park
	16/09/70	(Red hartebeest)	1		12	8			
	16/09/70	Oryx gazella gazella (Gemsbok)	1	ears			1		Mountain Zebra National Park
Knight, M Rechav, Y	x/06/76 x/06/77	Tragelaphus strepsiceros (Kudu)	25		159	143			Bucklands and Ulster farms, Great Fish River Valley
Rechav, Y	x/08/76 x/03/77	Angora goats and Bonsmara cattle	5^{14} 2^{14}		40 6	40 5			Bucklands farm
Baker, J	x/04/78 x/05/78	Shorthorn cattle Merino sheep Angora goats Antidorcas marsupialis marsupialis (Springbok)	16 ±500 1	Escutcheon feet feet	P P P P	P P P P			1° Jouberts Kraal 2° Libertas and Ashbourne (Davenpoort) Pearston district
Hall-Martin, A	05/09/78	Equus zebra zebra (Mountain zebra)	1	hooves	3	3			Mountain Zebra National Park
	24/12/78	Redunca fulvorufula (Mountain Reedbuck)	1		2	3			
Grobler, H		Oryx gazella gazella (Gemsbok)	1	legs	5	5	1		
Horak, I De Vos, V	06/12/79	Damaliscus dorcas phillipsi (Blesbok)	1		14	4			Mountain Zebra National Park
	06/12/79	Damaliscus dorcas phillipsi	1		8	2			Mountain Zebra National Park
	07/12/79	Oryx gazella gazella (Gemsbok)	1		103	81	2		Mountain Zebra National Park
	07/12/79	Oryx gazella gazella	1		111	40	4		Mountain Zebra National Park
MacIvor, K	23/02/81 27/07/81	Angora goats Boer goats	10^{15} 10^{15}	feet feet	173 57	260 103	110 63	31 4	Brakhill, Uitenhage North
	08/04/81	Tragelaphus strepsiceros (Kudu)	2	legs	6	1			Andries Vosloo Kudu Reserve
	24/06/81	Tragelaphus strepsiceros	1	legs	6		4		Brakhill
	18/08/81	Sylvicapra grimmia (Grey Duiker)	1	feet		2			Brakhill

KEY (TABLE 15)

n = the number of host animals inspected

n^x = the number of repeated inspections of n hosts

site = position on host animal from which R. glabroscutatum were obtained

* = type series for male and female R. glabroscutam

P = R. glabroscutatum present, number(s) unknown

1° = primary locality for host inspection

2° = secondary locality for host inspection

The remaining records were dispersed in the central Cape Province in the zone 32°21' to 33°54'S and 20°40' to 22°35'E.There are no records of R.glabroscutatum from coastal areas.

Table 14 lists information concerning the position, altitude, mean annual rainfall and vegetation of localities. R.glabroscutatum was recorded at an altitude range of ± 100m (Uitenhage) to ± 2000m (Mountain Zebra National Park, Cradock). The 'average' altitude for localities was ± 592m.

The mean annual rainfall of localities ranges from ± 200mm (Beaufort West and Oudtshoorn) to ± 600mm (Sommerset East). The 'average', mean annual rainfall of localities was ± 365mm.

Karoo and Karroid Bush accounted for 94% of estimated vegetational categories. This comprised 63% true Karoo and 31% false Karoo. The major types of true Karoo were Valley Bushveld (21%) Karroid Broken Veld (21%) and Central Lower Karoo (9%). False Karoo consisted of False Upper Karoo (23%) and False Karroid Broken Veld (8%).

6.3.2 Host records

The mountain zebra was the only example of a host of the order Perissodactyla (odd-toed hoofed animals). All other records were from bovid hosts (cattle and antelope) of the order Artiodactyla (even-toed hoofed animals) (Table 15).

6.4 DISCUSSION

6.4.1 Host localities

The locality records confirm the statement by Rechav (1981) that R.glabroscutatum occurred in localized areas of the south eastern Cape.

Although restricted in its distribution, R.glabroscutatum was recorded in areas in which much of South Africa's mohair is produced. Table 16 shows that in 10 localities (or districts) in which R.glabroscutatum has been recorded 49.8% of South African mohair was produced during 1979 and 1980.

TABLE 16 Mohair production (1979 to 1980) at 10 localities at which R.glabroscutatum has been recorded expressed as a percentage of the total production.

Locality name	Percentage of total mohair production*
Jansenville	10.9
Somerset East	9.6
Uitenhage	6.2
Cradock (Mountain Zebra Park)	6.1
Graaf Reinet	5.9
Steytlerville	5.1
Pearston	3.0
Beaufort West	1.6
Oudtshoorn	0.7
Middelburg	0.7
Total percentage	49.8

* From Van Der Westhuysen et al. (1981)

If the exploitation of Angora goats by R.glabroscutatum in these areas is at the level of infestation observed at Kudu camp then the economic implications of parasitism by this tick species are considerable.

Pegram, Hoogstraal & Wassef (1981) divide the genus Rhipicephalus into 3 ecological groups, namely, obligative hygrophiles, obligative xerophiles and facultative species. Classed an obligative xerophile Rhipicephalus pulchellus, a species not found in South Africa, is restricted in eastern Ethiopia 'to semi-arid plains and bushland below 2000m receiving 100-800mm rain' (Pegram et al., 1981). Adults were active in the rainy season (which included summer and autumn/spring rainfall areas) and parasitized goats, sheep, camels and cattle ((Ethiopia has the largest domestic animal population of any African nation including 12 million goats (Pegram et al., 1981)).

In South Africa R.glabroscutatum appears to be restricted to habitats similar to those occupied by R.pulchellus in eastern Ethiopia, with respect to vegetation, altitude, low annual rainfall and seasonal rainfall. On this basis R.glabroscutatum may similarly be classed an obligative xerophile.

6.4.2 Host records

When supplied, numbers recorded from hosts were generally very low with the exception of the moderate burdens recorded from goats (MacIvor, K.) and gemsbok (Horak, I.G. and De Vos, V.)(Table 15). Since the number of ticks recovered from an animal is related to the intensity and efficiency of the search, an accurate assessment of actual numbers occurring on hosts will only be possible once a uniformly effective method of destructive sampling has been adopted.

Table 15 shows that R.glabroscutatum was obtained from 10 species of wild ungulates. This does not support the claim that R.glabroscutatum has a narrow range of hosts (Rechav & Knight, 1981).

R.glabroscutatum was located on the legs and feet of small stock and small to medium sized game animals. Small numbers of ticks were found on the bodies of a few larger animals such as buffalo and Shorthorn cattle (Table 15). It appears that R.glabroscutatum occupies the same body sites on small to medium sized wild bovids as on small domestic stock.

Tick burdens obtained in the future by destructive sampling methods will indicate which wild species have the greatest potential as tick reservoirs for the contamination of small stock habitats.

6.5 CONCLUSION

Baker, cited by Hoogstraal (1978), claimed that R.glabroscutatum had become a common pest of South African domestic animals. On present evidence this claim must be qualified to include only the smaller domestic stock, sheep and goats. R.glabroscutatum classed an obligative xerophile, is a species restricted to the low rainfall areas of the south eastern Cape Province. This tick appears to have exploited the abundant supply of goat hosts in this region, an area where nearly half of South Africa's mohair is produced.

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