

STUDIES ON THE EFFECTS OF MICROCLIMATES
ON THE DISTRIBUTION OF LARVAL TICKS
IN THE EASTERN CAPE PROVINCE

by

M. K. Kraft B.Sc. (Hons).

being a thesis submitted for the degree
of Master of Science, Rhodes University.

DECEMBER, 1961.

CONTENTS

	Page
I - Introduction	1
II - Surveys of the Distribution of Larval Ticks	
1. Introductory Remarks	8
2. Larval Clusters	9
3. Methods of Survey	
(i) Apparatus	9
(ii) Survey Procedure	11
(iii) Definition of a Larval Cluster	12
(iv) Description of Areas Surveyed	13
4. Distribution of Larval Clusters in Micro- climatically Similar Areas.	15
5. Distribution of Larval Clusters in Micro- climatically Different Areas	
(i) <u>B. decoloratus</u>	16
(ii) <u>I. pilosus</u>	23
(iii) <u>R. evertsi</u>	29
(iv) <u>A. hebraeum</u>	29
6. Conclusions	31
III - Studies on the Development of Larval Ticks in Microclimatically Different Field Situations.	
1. Introductory Remarks	33
2. Observation Plots	33
(i) Plots at Mount Pleasant	35
(ii) Plots at Hounslow	37
3. Climatic/.....	

	Page
3. Climatic Conditions	
(i) Methods of Measurement	40
(ii) Climate Relations between Plots at Hounslow	44
(iii) Climate Relations between Plots at Mount Pleasant	46
(iv) Climate Relations between Farms	47
4. The Ticks	
(i) Sources of Engorged Female Ticks	49
(ii) Methods of Confining Ticks	50
(iii) Examination of Ticks	52
5. Effects of Climate on Rate of Development	
(i) Examples of Faster Development in 'Warmer' Situations	53
(ii) Examples of Slower Development in 'Warmer' Situations	56
6. Effects of Climate on the Survival of Prelarval Ticks	59
(i) Probably Sudden Deaths under Hot/ Dry Conditions	59
(ii) Possibly Gradual Deaths under Hot/Dry Conditions	62
(iii) Probably Sudden Death under Cool/ Moist Conditions	64
(iv) Possibly Gradual Deaths under Cool/Moist Conditions	64
7. Comparison of Survey and Plot Results.	65
8. Conclusions	70

IV - Observations on the Behaviour of Engorged
Females and Larvae of B. decoloratus.

1. Introductory Remarks	73
2. Behaviour of Larval Ticks	
(i) The Observations	74
(ii) Possible Causes of Horizontal Migrations	76
(iii) Possible Effects of Horizontal Migrations on the Distribution of Larval Clusters.	77

3. Wandering/.....

	Page
3. Wandering and Settling-down of Engorged Female Ticks	79
(i) Methods	80
(ii) Results	81
(iii) Possible Factors Affecting Wandering and Settling	86
(iv) Possible Effects of Wandering and Settling on the Distribution of Larval Clusters	92
4. The Falling of Engorged Female Ticks from their Hosts	94
(i) Pattern of Engorgement and Falling of Female Ticks	96
(ii) Host Activity and Tick-fall	99
(iii) Climatic Conditions and Tick-fall	101
(iv) Possible Effects of Tick-fall on the Distribution of Larval Clusters.	102
5. Conclusions	103
V - Summing Up	107

List of References.

Appendices.

Aknowledgements.

SUMMARY.

1. In studying the effects of micro-climates on the distribution of larval ticks in the Eastern Cape Province four species were considered, namely, Boophilus decoloratus (Koch), Rhipicephalus evertsi(Neu), Amblyomma hebraeum (Koch) and Ixodes pilosus (Koch).
2. Three types of investigation were made:-
 - i) autumn and spring surveys of the distribution of larval clusters, which were assumed to be close to positions in which egg-masses had been laid. - (Four species);
 - ii) observations on the survival and development of eggs and engorged female ticks in microclimatically distinct field plots. - (Four species);
 - iii) observations on the behaviour of the larvae and of the engorged female ticks. - (B. decoloratus).
3. The survey and plot data suggest that in autumn larval clusters of I. pilosus were to be found only in well-shaded situations because more exposed places were micro-climatically unfavourable to the survival of earlier stages.
4. The surveys show that in spring 1957 larval clusters of I. pilosus were to be found in unshaded, as well as in shaded, situations.
5. The survey and plot data indicate that the winter of 1957 was not favourable to the development of larvae of B. decoloratus, and that in spring new larval clusters may be expected to appear first in the warmest situations and later in the generally cooler places.

6. The plot data show that during hot and dry periods exposed situations were unfavourable to the engorged females and eggs of all four species considered, but that during such periods these stages could sometimes survive in well-shaded places.
7. The survey and plot data show that in autumn and in spring larval clusters of B. decoloratus and R. evertsi may be present in unshaded situations.
8. The plot investigations provide little information about the distribution of larval clusters of A. hebraeum, but the survey data suggest that it is not remarkably different from that of B. decoloratus and R. evertsi.
9. There is a discrepancy in the survey and plot data: the surveys show that larval clusters of R. evertsi and B. decoloratus were rare or absent from well-shaded situations, whereas the plot data suggest such situations were micro-climatically favourable to larval development during the months preceding autumn.
10. The observations on the behaviour of larvae and engorged females of B. decoloratus provide information which suggests that the behaviour of these stages may account for the rarity of larval clusters in well-shaded places.
11. The relative density of larval clusters of B. decoloratus is evidently also affected by factors other than micro-climate. The dropping-off behaviour of engorged female ticks appears to be possibly important in this.

Chapter I - INTRODUCTION.

At present in South Africa the several species of tick pests are controlled to some extent by acaricidal treatment, or 'dipping', of domestic animals, and attempts are made to prevent tick-borne diseases by inoculation. A considerable amount of research has been done on these aspects of the tick problem in the republic (e.g. Whitehead & Baker, 1960; Neitz & Alexander, 1945) but there is a remarkable dearth of information about the ecology of tick pests. In the past few years efforts have been made to remedy this lack (Stampa 1959) since the results of workers in other countries have shown that ecological knowledge is useful, not only as a basis for 'natural' control measures such as rotational grazing (Wilkinson, 1957), but also for the intelligent application of the 'unnatural' measure of chemical control (Norris, 1957).

The present ecological investigation was conducted in the Eastern Cape Province. Four ixodid ticks were studied, namely, Ixodes pilosus (Koch) and Amblyomma hebraeum (Koch) which are three-host species, Rhipicephalus evertsi (Neu)

a two-host tick, and ticks of the species Boophilus decoloratus (Koch) which attain a host only once during their life-cycle.* The investigation was limited to the non-parasitic stages common to all ticks, namely, the engorged females, the eggs and the unfed larvae. The aspect of central interest was the effects of microclimates (Geiger, 1950) on the distribution of the unfed stages. Previous/.....

* See Neitz (1956) for disease relations.

Previous workers have surveyed the distribution of the unfed ticks which are 'waiting for a host' and have found that the larvae frequently occur in clusters at the tips of the vegetation. This is clearly because a parent female will lay eggs in a large mass at the base of the vegetation, from whence the larvae eventually migrate vertically and thus form groups more or less immediately above the hatching site (Koslowski, 1953; Snowball, 1957).

In the present investigation the distribution of larval clusters was surveyed in autumn and in spring. This provides a picture of the types of situations in which engorged female ticks laid eggs, and where the eggs successfully developed, during warm and cold months respectively. On the basis of the results obtained from the autumn surveys, field situations were chosen for the introduction of engorged female ticks. For several months the survival and development of 'prelarval' stages were investigated in these plots. Originally it was intended that the longevity of larvae in micro-climatically different field situations would also be studied, so that there would be a better basis for comparison of survey and plot results, but the plots proved to be too small to permit the release of many groups of larvae.

Investigations of effects of tick behaviour on the distribution of larval clusters were also made, B. decoloratus being the species most studied in this regard. At a fairly early stage an opportunity arose for a preliminary study of the falling of engorged female ticks from their hosts, but it was in the second year of the investigation that further observations

were/.....

were made on this and other relevant aspects of behaviour.

At various times indications were obtained which suggested that the behaviour of the hosts of B. decoloratus affect the distribution of the larval clusters. Also it was evident that predators might have a considerable effect on larval distribution and abundance in the case of all four species. These two aspects have been considered to a small extent in the present thesis.

In brief, the general hypotheses examined to a greater or lesser extent are:-

- (i) within an infested area, the distribution of clusters of larval ticks of the species considered is partly determined by microclimatic differences;
- (ii) microclimatic conditions affect the distribution of larvae partly by directly affecting the survival of engorged females and eggs and the development of the latter;
- (iii) microclimatic conditions affect the distribution of larvae partly through their effects on the behaviour of engorged female ticks and of the larvae themselves;
- (iv) microclimatic conditions affect the distribution of larval ticks partly through effects on the distribution and activities of animals associated with the engorged females, eggs or larvae, for example the hosts of the females.

These/.....

These four hypotheses are considered in the three following chapters, namely Chapters II, III and IV. In Chapter V the main conclusions emerging from the investigation are summarised and possible practical implications are briefly mentioned.

Chapter II - SURVEYS OF THE DISTRIBUTION OF LARVAL TICKS.1. INTRODUCTORY REMARKS.

Although the investigation was spread over two years, only part of this period was spent in surveying the distribution of larval ticks. Two series of surveys were made, one in the late summer and the autumn of 1957, and the other, to provide a possibly contrasting picture, in the spring of the same year. The table below indicates when and where the surveys were made and the map at the end of this chapter shows the positions of the farms mentioned. The farms were macro-climatically quite distinct as indicated by the climate data in Fig. 1.

Table 1.

<u>Farm</u>	<u>District</u>	<u>Autumn Survey</u>	<u>Spring Survey.</u>
Trent	Bathurst	26/ii - 8/iii/57	13/iix - 15/iix/57
Grandon	Bathurst	26/iii-27/iii/57	No survey.
Seaview	Alexandria	5/iv -11/iv/57	28/iix - 1/ix/57
Fort Willshire	Victoria East	23/iv -30/iv/57	18/ix - 21/ix/57

Contrary to initial hopes none of the four farms was found to be well-infested with the larvae of more than one species of ticks. I. pilosus was abundant at Seaview but was not found on the other farms. The larvae of B. decoloratus were quite common at Trent, but occurred in smaller numbers elsewhere. A few larval clusters of R. evertsi were found on all four farms, and A. hebraeum was established at Trent, Grandon and Fort Willshire although the larvae of this species were not numerous on any of them.

2. LARVAL CLUSTERS.

Larval ticks were found on the tips of vegetation where they occurred in fairly compact clusters. In view of the results obtained by previous workers (Kosłowski, 1953; Snowball, 1957; Gray, 1957) it seemed that larvae in a cluster existed close to the site where the parent female tick had settled and laid her hundreds or thousands of eggs. On the other hand, apparently isolated larvae may have been carried far from their hatching site, either by wind (Snowball, loc. cit.), or by animals to which they had failed to become attached, and they might have arrived in a place only a short while before being found there in a survey. Thus particular attention was paid to the distribution of larval clusters, and 'isolated larvae' (see 3.iii) were largely ignored.

3. METHODS OF SURVEY.

Essentially the surveys involved both the discovery of larval clusters at the tips of vegetation and description of the places surveyed.

(i) Apparatus.

The apparatus mainly used was a modified version of that designed by Stampa (1959) for the survey of larvae of Ixodes rubicundus (Neu) in the Karroo. He used a wooden bar about 2 m. in length, to which 12 'tails' of white flannelette were attached. Each tail was a rectangular piece of fabric, about 10 cm. x 45 cm., doubled longitudinally and sewn to form a tube, with the fluffy side out. Stampa found that this apparatus was effective in brushing ticks from vegetation tips, and that, once on a tail, the ticks were usually sufficiently entangled/.....

entangled in the fluff of the flannelette to remain there even if the apparatus was dragged over more vegetation before the tail was examined. The narrow tails were more suitable than the 'blankets' (MacLeod, 1932) and 'flags' (Philip, 1937) of other workers, since in uneven vegetation some of the tails drop down between the higher standing parts and so brush against the lower tips as well. The blankets and flags tend to ride over the higher vegetation only and thus miss too many ticks.

I found that the tails had another advantage. After use they could be easily stored in glass tubes and the ticks on them could be removed later, a large stock being carried around to replace tick infested tails with clean ones. Workers using blankets or flags have to remove ticks from the fabric in the field, a procedure which wastes time.

The 'tail-bar' used in the present investigation differed in two respects from that used by Stampa. (a) The bar was shorter, 120 cm. being a more convenient length for a bar which had to be dragged, in some cases, through fairly close-growing bush; (b) the tails were simple strips, 5 cm. x 45 cm., tubular tails being an unnecessary refinement since larvae were picked up by both fluffy and less fluffy sides of the flannelette.

The tail-bar was dragged behind the surveyor by means of a rope, and was periodically examined for larval ticks. Tick-infested tails were removed, rolled up and stored in labelled glass tubes which were stoppered with cotton wool. At the end of a day's survey, the larvae on each tail were counted, identified and/.....

and removed to tubes of 5% formalin.

(ii) Survey Procedure.

The usual procedure in surveying for larval ticks was as follows:-

(a) Larval clusters at the tips of vegetation were sought with the tail-bar, which was dragged over various parts of a farm. The tails were examined for larvae after every 'drag' of 30 to 50 paces and as far as possible the drags were made in a straight line to facilitate the second part of the procedure.

(b) If larval ticks were found on the tails, the area covered in the last drag was carefully resurveyed until the remains of one or more clusters of the same species were found on the vegetation.

(c) Survey of surrounding areas with similar characteristics was then made with drags of 10 - 30 paces, in an attempt to discover further clusters.

(d) If this search for more clusters was unsuccessful, a microclimatically different area was examined, the length of drags being increased to 30 - 50 paces, until yet another indication of larval infestation was found.

(e) If the search for more clusters within a microclimatically fairly uniform area was successful, the 10 - 30 pace drags were continued in nearby areas in an attempt to discover the limits of the infestation.

In places where there were numerous clusters of larvae of apparently the same species, each cluster was not tracked down to its exact position, unless the vegetation covered in a drag was clearly varied. It

was/.....

was found that surveys could not be made when the vegetation was very wet since under these circumstances larvae were easily washed off the tails.

(iii) Definition of a Larval Cluster.

A larval cluster was presumed to constitute a group of larvae which had settled on the vegetation tips not more than a few centimetres horizontally away from the group of eggs from which they had hatched (cf. Chap. IV 2.)

In the present investigation it did not matter if larvae from two parent females were considered to form one cluster, or if larvae from one group of eggs were noted as two clusters; the survey was only roughly quantitative. However, for the sake of recording data in a fairly uniform and simple fashion, it was decided that where a large number of larvae, say more than 100, were found on the eight tails and their distribution along the length of the bar formed more than one distinct peak, it would be assumed that more than one cluster had been struck in the drag yielding the larvae.

More precision was needed in consideration of small numbers of larvae since it was important not to mistake for clusters larvae which had been found far from their hatching sites. To avoid such an error and for the sake of simplicity, it was decided that only if three adjacent tails on the tail-bar were found to have on them a total of at least 10 larvae of any one species, would these larvae be considered to have been collected from a cluster.

(iv)/.....

(iv) Describing the Areas Surveyed.

Notes were made on the structure of the vegetation, whether it was living or dead, topography, and soil features which may have determined the microclimatic differences of the areas surveyed. The weather conditions and the temperature at the time of surveying was sometimes recorded in case the collection of larvae was considerably affected by climatic conditions.

The places surveyed can be classified as follows:-

TOPOGRAPHY.A. Relatively high-altitude parts of a farm.

- (a) North-facing slopes;
- (b) North-West-facing slopes;
- (c) West-facing slopes;
- (d) Level ground, North-east and South-west facing slopes;
- (e) East-facing slopes;
- (f) South-east-facing slopes;
- (g) South-facing slopes.

The slope categories have been arranged as far as possible from the warmest and driest to the coolest and wettest. In the southern hemisphere, northerly aspects are the most exposed to the heat of the sun, and southerly aspects the least exposed. West slopes are in general hotter and drier than east slopes because the climate of the latter is modified by the presence of dew in the mornings (Geiger 1950). North-west and south-east slopes would be expected to be microclimatically intermediate as shown in the list above.

A/.....

A north-east slope is hot inasmuch as it is north-facing and cool inasmuch as it is east-facing; a south-west slope is cool inasmuch as it faces south and hot inasmuch as it is west-facing. Thus, these rather contradictory types of slopes have been grouped together with level ground which is in a middle position in the graded series of slopes of different aspects.

B. Relatively low-lying parts of a farm. (Photos 1 and 2).

1. Hollow or Small Valley
2. Large Valley with no river;
3. Large Valley or Deep Ravine with river.

A finer classification of topography is unwarranted in the present investigation.

VEGETATIONAL COVER (Photos 3 - 15).

1. Complete Over-head Cover.
2. Incomplete Over-head Cover.
3. Laterally-sheltered Medium-height Grass.
4. Laterally-sheltered Short Grass.
5. Tall Grass.
6. Medium-height Grass.
7. Short Grass.
8. Sparsely-growing Grass with Scattered Stones.
9. Sparsely-growing Grass with No Stones.

The categories of vegetational cover are illustrated and described at the end of this chapter. They have been arranged in a sequence, ranging, as far as is possible in a simple classification, from vegetation providing the most cover to that providing the least protection from extremes of heat, cold, dryness and wind (Geiger 1950).

Soil/.....

SOIL

In general it can be said that the surface soil of Trent and Grandon was loamy, that of Seaview sandy, and the soil at Fort Willshire was mainly clayey. The vegetation covering the soil must have had a profound effect on it, doubtless determining the type and quantity of plant debris deposited on the soil, and also affecting the rate at which it decomposed. Vegetational cover and topography probably determined how much of surface soil and debris was moved from place to place by wind and water.

Since most of the surface soil characteristics of each farm appeared to be determined by vegetation and topography, notes on the soil features were not frequently made. However, the compactness of the soil was considered to be important since the climates of loose soils are, in general, more fluctuating than those of firm soils, especially if the soils are exposed.

4. DISTRIBUTION OF LARVAL CLUSTERS IN MICRO-CLIMATICALLY SIMILAR AREAS.

The density of larval cluster distribution of each species appeared to vary from place to place. Much of this variation may have been caused by microclimatic differences, but at least in the case of B. decoloratus other factors seemed to play a part. Thus all the areas infested with larval clusters of this species were surrounded by apparently uninfested areas which were not remarkably different. As will be seen in the next section, the larvae of B. decoloratus were found in a wide variety of micro-climatically different field situations which suggests that the patchy distribution was not because of some subtle difference between/.....

between infested and apparently uninfested areas.

The patchy distribution may have been due to the herding behaviour of cattle, which are the favoured host of the species (Arthur, 1960). In fact some evidence was obtained at Trent and Seaview which indicates that cattle were important: (a) Medium-height Grass in a camp at Trent called Bananas Camp yielded several clusters of the larvae of B. decoloratus. Cattle passed through this camp on one day each fortnight on their way to and from the 'dip'. On the other hand, on the same morning, in a thorough survey of an adjacent camp, the Nursery, not a single larva of B. decoloratus could be found even in parts which seemed micro-climatically similar to the infested parts of Bananas Camp. The Nursery had been free of cattle for seven months before this survey. (b) At Seaview and the adjacent farm there was a notable state of affairs. Only one cluster of B. decoloratus was found at Seaview, whereas on the adjacent farm numerous clusters were found in situations which were climatically neither more nor less extreme than many places surveyed at Seaview. Differences in the programme of cattle-dipping may have been the reason for this apparent discrepancy (cf. Theiler, 1949).

5. DISTRIBUTION OF LARVAL CLUSTERS IN MICRO-CLIMATICALLY DIFFERENT AREAS.

(1) B. decoloratus.

At Trent, larval clusters of this species were in some places sufficiently numerous to permit comparison of the density of infestation of adjacent

areas/.....

Table 2. - Clusters of the larvae of *B. decoloratus* found in infested parts of Trent, (in parenthesis the approximate height of the highest parts of the vegetation covered).

Camp	Topography	Structure of Vegetation	Notable soil features	Number of		
				Drags	Paces/ Drag	Clusters
AUTUMN Bananas Camp	Slight S-E slope; low with respect to rest of farm	Dense green grass(25 cm.)	Firm	23	20-30	8
		Patches of dense green grass (5 cm.)	Firm	15	30	2
		Tall dead weeds (60cm) & weed seedlings(2 cm.)	Quite loose	12	30	0
Bush Camp	Slight N-W slope, high relative to rest offarm.	Area 1. Coarse green grass(5cm) unshaded.		6	30	4
		Dense green grass(4cm)under slight tree.		2	14	1
		Two nearby tree clumps.	Much leaf debris.	6	30	0
		Area 11. Coarse green grass(4cm) unshaded.		3	20	3
		Nearst tree clump.	Much leaf debris.	3	30	0
Gum Trees Camp	Slight W slope;high relative to rest of farm.	Tufts of green grass (10cm) between Bushes (2m).		46	10	(11 { 0
		Dense green grass(25cm) above bushy zone.		12	10	12
		Coarse green grass (6cm) below bushy zone.		12	10	2
SPRING Legg's Camp	N. slope	Rocky with tufts of grass (15cm) & bare patches of ground		2	20 or less	3
	N-E slope	do.		6	do.	7
	S-W slope	do.		3	do.	0
	S-E slope; steep.	Less rocky, with tufts of grass (10cm) & bare patches of soil		12	do.	0
	Level ground in hollow between S-E & N-W slopes	Short grass, no stones.		5	do.	2

areas. In autumn clusters were numerous in parts of three camps, namely Bananas Camp, Bush Camp and Gum Trees Camp. In spring, only part of Legg's Camp was heavily infested. The relevant data for these four camps are presented in Table 2.

Bananas Camp (Autumn).

The area surveyed was a fallow land together with its unploughed fringe. This fringe was covered with densely growing Medium-height Grass, while the land, which had some years ago been under pineapples, was, at the time of the survey, covered with the dry stalks of weeds standing about knee-high, and, at lower levels, by groups of tiny seedling plants with, here and there, a patch of close-growing, fairly short grass. The land sloped down to the edge of a small stream, the aspect of the slight slope being eastern.

The data presented in Table 2 indicate that the grassy fringe was more heavily-infested with the larvae than was the fallow land itself; and that in the land, only grassy patches harboured the larvae. Where the soil of the land was loose and sparsely-covered no larval clusters were found.

Bush Camp (Autumn).

The Tree Clump Savannah of this camp was on very slightly sloping ground almost at the crest of one of the 'undulations', which were characteristic of Trent.

Although larval clusters of B. decoloratus were found here and there on the Short Grass between the tree clumps, and in one place on short grass with Incomplete Overhead Cover, not a single larva could be found under the Complete Overhead Cover provided

by/.....

by three tree clumps not far from the two infested patches of grass.

Gum Trees Camp (Autumn).

The infested part of this camp was on a slight westerly slope about half-way up the side of an undulation. It was in a corner of the camp, i.e. the infested part was bordered on two sides by fences at right angles to one another. Beside one fence, which ran along the contour of the slope, there was a grassy road. Here the ground had been levelled and the grass was dense Medium-height Grass (Photo 11). Below the road, in a zone about 20 m. wide, there was scattered bush with grass and shrubs growing between large and small bushes (Photo 7). At a slightly lower level, beyond the scattered bush, there was an 'open' area where the soil was fairly well covered with short-cropped grass (Photos 12 and 13).

Larval clusters were found on grass in all three zones but no clusters were found on any of the bushes or shrubs in the zone of scattered bush (cf. Chap. IV 2.iii). The data presented in Table 2 suggest that perhaps the road was the most infested, the zone of scattered bush less, and the short grass in the open the least infested.

Legg's Camp. (Spring).

In spring, the only place where numbers of larval clusters of B. decoloratus were found was at Trent in part of Legg's Camp. In this place there were rocky slopes all with partial cover of tufted grass. Some of the slopes fell away into a small valley or Hollow (Photo 2), while one sloped more steeply into a

low-lying/.....

low-lying gulley. The slopes presented several aspects as shown in the Table 2.

The data presented in Table 2 suggest that the north and north-easterly slopes were heavily-infested with B. decoloratus, while the cooler south-west and south-east slopes were apparently free of the larvae. Two larval clusters of the species were found in the Hollow between north-east and south-west slopes. The only other cluster of B. decoloratus to be found at Trent in spring was on fairly dense but short tufted grass on a very slight north-east slope, i.e. also in a relatively warm situation.

Results obtained from the surveys of the four 'well-infested' parts of Trent can be summed up as follows:

In Autumn,

- (a) No larvae were to be found in the tree clumps near infested open grassy areas in Bush Camp;
- (b) in Bananas Camp no clusters were to be found in the grassless parts of the old land with its rather loose soil, whereas the grassy fringes of the land yielded several clusters;
- (c) in the infested part of Gum Trees Camp the least infested area was the part with least vegetational cover;

In Spring,

- (d) larval clusters were to be found only in the warmest parts of the farm.

The data obtained from the less-infested parts of the farms appear to be mainly compatible with these results.

Reference/.....

Table 3. - Types of Situations yielding clusters of B. decoloratus.

	Categories of Degree of Vegetation Cover									
	1	2	3	4	5	6	7	8	9	
AUTUMN North							F			
North-West		T					T			
West			T			T	G	T		T
Level, etc.			S	F		T	T	T	G	
East						T	T			
South-East						T	F			F
South						G				
Hollow										
Large valley with no river										
Ravine, or valley, with river.			G	G				F		F
SPRING North								T		S
North-west										
West								T		
Level, etc.						S	S	T	T	
East										
South-east										
South										
Hollow							T			
Large valley with no river										
Ravine, or valley with river.		F	F				F		F	

Symbols: T - Trent; G - Grandon; F= Fort Millshire; S= Soaview & adjacent farms.

The 'aspects' mentioned were on the upper parts of slopes.

Reference to Table 3 will show that no larval clusters of B. decoloratus were found in Complete Overhead Cover on any of the four farms surveyed in autumn. In one place, at Trent, clusters were found in a place which was as unsheltered by vegetation as was the fallow land in Bananas Camp but this area was peculiar since it was near a water hole and appeared to be perpetually damp.

On the other hand at Fort Willshire, which was a hotter and drier farm, a cluster of larvae of B. decoloratus was found on a dry south-east slope where the vegetation was even more scant. True the larvae were clustered on a little shrub with green leaves, but the soil near the base of the shrub had little cover besides wisps of dry grass and small chips of slate.

How do the results obtained from the less-infested farms tally with the spring picture at Trent? The data appear to be explicable if one supposes that larvae of B. decoloratus were unable to develop or to survive during most of the winter, but that eventually those eggs in the warmer situations were the first successfully to complete development. At Trent, which was surveyed in the middle of August, the distribution of larval clusters was the most restricted; Seaview, which was surveyed about a fortnight later, appeared to have a slightly wider distribution; and Fort Willshire which was surveyed last, in the latter half of September, had a considerably wider distribution in terms of vegetational cover, although the clusters on this relatively dry farm were apparently limited to places/.....

places beside rivers or in riverbeds. Perhaps if Trent had been surveyed immediately after the spring survey of Fort Willshire, larval clusters of B. decoloratus would then have been found over a wide range of vegetational cover, since by that time larval development in the cooler parts of the farm might have been successfully completed.

(ii) I. pilosus.

Seaview was the only farm where larvae of I. pilosus were found during the surveys. In autumn, parts of three camps on that farm were sufficiently well-infested to provide a clear indication of the limits of larval cluster distribution in those areas. These camps were called '2-N', '3-N' and 'Grassy Camp'. In spring, the level of larval infestation appeared to be much lower but although the limits of the spring distribution were not clear, it is of interest to compare the results obtained in the two seasons. Camp 2-N (Autumn).

Camp 2-N was a large camp and included a variety of vegetational cover. In comparing the density of larval clusters there, the types of vegetation considered were:- Alexandria Forest (Acocks, 1953) which provided Complete Overhead Cover; part of the forest's fringe providing Incomplete Overhead Cover; Tall to Medium-Height Grasses Laterally Shaded by the forest and by trees near the forest; more open grass which was also Tall to Medium-height Grass. The ground of the camp was somewhat uneven, but, in the parts surveyed it was fairly level.

Table 4 shows that in the area with Complete Overhead Cover the larval infestation was great.

Indeed/.....

Table 4 - Clusters of the larvae of I. pilosus found in the infested parts of Seaview in autumn (Numbers in parenthesis as in Table 2)

Camp	Topography	Structure of Vegetation	Notable soil features	Number of		Clusters.
				Drags	Paces/drag	
2-N	Mainly level or slightly sloping to south.	Alexandria Forest, Canopy 3-4 m; substorey vegetation scant & various in type and in height.		6	10	Clusters too numerous and vegetation too uneven to allow count.
		Fairly dense green grass (8cm.) in overhead shade of forest edge		8	10	5 - 6
		Mixed grass (30-40cm.) partly yellow; within few metres of forest edge		25	20	27 larvae but NO CLUSTERS
		Mixed grass as above but away from forest		Many	40	0
3-N	Short but steep south slope.	Dense thicket, 7m. long, 5m. wide and 2m. high		1	10	Too many to count.
	slight south slope	Complete ground cover of short green grass (2cm.) just below thicket.		1	10	0
		Scant cover of short yellow grass tufts (4cm.); just above thicket		1	20	0
Grassy Camp	Level	Under large trees with low (10cm.) subvegetation.	Sandy & loose	2	20	Numerous larvae
		Scattered shrubs (1m.) not far from the trees.	Sandy & loose	1	20	0
	south slope - level	Short & Medium height grass (3-12 cms.)	Compact soil	Many	20	0

Indeed, the density of the infestation and the unevenness of the substorey vegetation on which the larvae were clustered, made it impossible to distinguish clusters of larvae probably from different parent females. The infestation appeared to decrease as the degree of shelter grew less, until the unsheltered grass several yards from the edge of the forest seemed to be free of isolated larvae as well as of larval clusters.

Camp 3-N (Autumn).

Numerous larvae of I. pilosus were found in a thicket or hedge growing on a fairly steep southerly slope in Camp 3-N. The thicket was about 7 m. long, 5 m. wide and 2 m. high. It was exceedingly dense and quite impenetrable except at one point where there was a narrow pathway, which just permitted one to push one's way through the width of the thicket. In passing thus along the pathway I became 'covered' with larvae of I. pilosus.

Above the thicket there was a small clearing, where the vegetation consisted of short tufts of rather yellow grass. No larvae of I. pilosus were found on this Laterally-Sheltered Short Grass. Below the thicket, the slope of the ground became more gradual and here there was dense Short Grass which was green. No larvae of I. pilosus were found in this place.

Grassy Camp (Autumn).

Grassy Camp was one of the smaller camps at Seaview, although it was several morgen in extent. Almost the whole camp was covered with grass; mainly

Short/.....

Table 5 - Types of situations yielding larval clusters of I. pilosus.

	Categories of degree of vegetational cover									Remarks
	1	2	3	4	5	6	7	8	9	
<u>AUTUMN</u>										
North										
North-west										
West										
Level, etc	S	S								
East										
South-east										
South	S	S								slope S ₁ = steep
Hollow										
Large valley with no river		S								S ₂ = east slope near valley base.
Ravine, or valley with river.										
<u>SPRING</u>										
North										
North-west										
West										
Level, etc.	S	S	S							
East										
South-east										
South				S		S				
Hollow	S									
Large valley with no river										
Ravine, or valley with river.										

Symbols: T= Trent; G= Grandon; S= Seaview; F= Fort Willshire.

The aspects mentioned were on the upper parts of slopes.

Short Grass where the ground sloped with southerly aspect, mainly Medium-height Grass on almost level ground at the bottom of the slight slope. There were some groups of large trees and also a few large bushes.

The camp was extensively surveyed, but clusters of I. pilosus were found only near or under the shelter of trees. There were numerous clusters in two tree clumps providing Complete Overhead Cover.

In all three of the abovementioned infested camps the larval clusters of I. pilosus were found only in well-sheltered situations, and the contrast between the heavy infestation of such places and the absence of clusters in nearby more open areas was striking. Three larval clusters of I. pilosus were found in situations other than those already specifically mentioned, all in well-shaded situations.

On the other hand, in spring the picture appeared to be different (see Table 5). The larvae were present once again in well-shaded and laterally sheltered situations, although not in exactly the same places as in autumn, but a notable change was the presence of the larval clusters in quite exposed situations. The two most exposed clusters were found in Grassy Camp, where the ground was sloping slightly to the south. One was on a low-growing shrub near the east fence, the other was on Medium-height Grass in a completely unsheltered place.

The results of the surveys at Seaview indicate that in autumn larval clusters of I. pilosus were

restricted/.....

Table 6 - Types of Situations yielding larval clusters of R. evertsi.

	Categories of degree of vegetational cover.									Remarks
	1	2	3	4	5	6	7	8	9	
<u>AUTUMN</u>										
North										
North-west										
West			T							T
Level, etc				S	G		T	S		F
East				F						
South-west							S			
South										
Hollow										
Large valley with no river										
Ravine, or valley with river.			F			F				
<u>SPRING</u>										
North										
North-west										
West			T			S				
Level, etc			S		F					
East										
South-east										
South										
Hollow										
Large valley with no river										
Ravine, or valley with river.										
Symbols: T= Trent; G= Grandon; S= Seaview; F= Fort Willshire.										
The aspects mentioned were on the upper parts of slopes.										
Symbols: T= Trent; G= Grandon; S= Seaview; F= Fort Willshire.										
The several aspects mentioned were on the upper parts of slopes.										

restricted to places with overhead, or considerable lateral shelter. In spring the clusters were to be found in the open places as well as in the shade.

(iii) R. evertsi.

Seaview was the farm which yielded the most larvae of R. evertsi but even on this farm not enough were found to provide a picture of distributional limits. Table 6 shows the whole range of places in which larval clusters of R. evertsi were found in the autumn and the spring surveys. It will be noticed that in both seasons the larval clusters were found in fairly sheltered places, but not where there was over-head shade. This failure to find the clusters under trees and in forests may be significant. At the other end of the range, it can be seen that a cluster was found in one of the most exposed and hottest parts of Trent, and this in autumn, i.e. after the hot season of the year.

(iv) A. hebraeum.

In autumn the farm yielding most A. hebraeum was Grandon. However, even on this farm there were no notable concentrations of larval clusters of this species, and thus the relative density of the clusters in different microclimates cannot be considered. Table 7 indicates the types of situations in which larval clusters of A. hebraeum were found on all farms surveyed in the autumn and spring. The topography of the situations yielding the larval clusters was varied, and the range of vegetational cover of such places was wide. It happened that no clusters were found in situations

where/.....

Table 7 - Types of situations yielding larval clusters of A. hebraeum.

	Categories of degree of vegetational cover.									Remarks	
	1	2	3	4	5	6	7	8	9		
<u>AUTUMN</u>											
North				F							
North-west											
West						G					
Level, etc.		G F	F		T	T					
East											
South-east											
South		F		F		G			F		F2=steep slope
Hollow						G	G				One of G6 steep slopes
L Large valley with no river											
Ravine, or valley with river											
<u>SPRING</u>											
North											
North-west											
West											
Level, etc.				F							
East											
South-east											
South		F									
Hollow											
Large valley with no river.											
Ravine, or valley with river		F	F								

Symbols: T= Trent; G= Grandon; S= Seaview; F= Fort Willshire.
The aspects mentioned above were on the upper parts of slopes.

where there was complete shade, and it is possible that such places were unfavourable to these ticks. Only two clusters were found in vegetation more scanty than Medium-height Grass. One of these was found at Grandon on short grass beside a low shrub in a Hollow, a place in some respects similar to a Laterally-sheltered situation. More remarkable was the presence in autumn at Fort Willshire of a cluster in a high place where the only vegetation was small tufts of faded grass (10cms.) The presence of stones here might have been significant, since conditions under stones are usually relatively moist.

In spring, clusters of the larvae of A. hebraeum were found only at Fort Willshire. The embryological development of this species is of much longer duration than that of the other three species considered here (Lounsbury, 1905) and this may be why, after the cool winter months, the larval clusters of this species were found only on the warmest farm, which was also the last to be surveyed in spring.

6. CONCLUSIONS.

- (i) The distribution of the larval clusters of B. decoloratus appeared to be patchy, at least in autumn, and seemed to be considerably affected by the distribution of cattle.
- (ii) In autumn at Seaview the larval clusters of I. pilosus appeared to be limited to situations with Complete Overhead Cover or Incomplete Overhead Cover, while in spring the clusters were to be found also in more open situations.

(iii)/.....

- (iii) It appeared possible that situations with Complete Overhead Cover were climatically unfavourable to B. decoloratus, R. evertsi, or A. hebraeum, since the larval clusters of these species were not found in such places. At the other end of the range of vegetational cover, there were indefinite indications that situations with sparse vegetation and no stones could also be unfavourable to the successful development of larval ticks. Larval clusters of these three species were found at one or other farm in most categories of vegetational cover between these two extremes, but the absence of clusters on bushes was puzzling.
- (iv) In most cases infested patches were too small to permit comparison of situations which differed mainly in topography, but, in spring at Trent, slopes of various aspects with Sparse Grass and Stones could be compared and it appeared that the clusters of B. decoloratus were to be found only on the warmer aspects at this time of the year.



— MAGISTERIAL BOUNDARIES
(NUMBER)-ALTITUDE IN METRES

MILES 10 5 0
KILOMETRES 10 5 0

● - FARMS ON WHICH TICK INVESTIGATIONS WERE CONDUCTED.

TOWNS-□

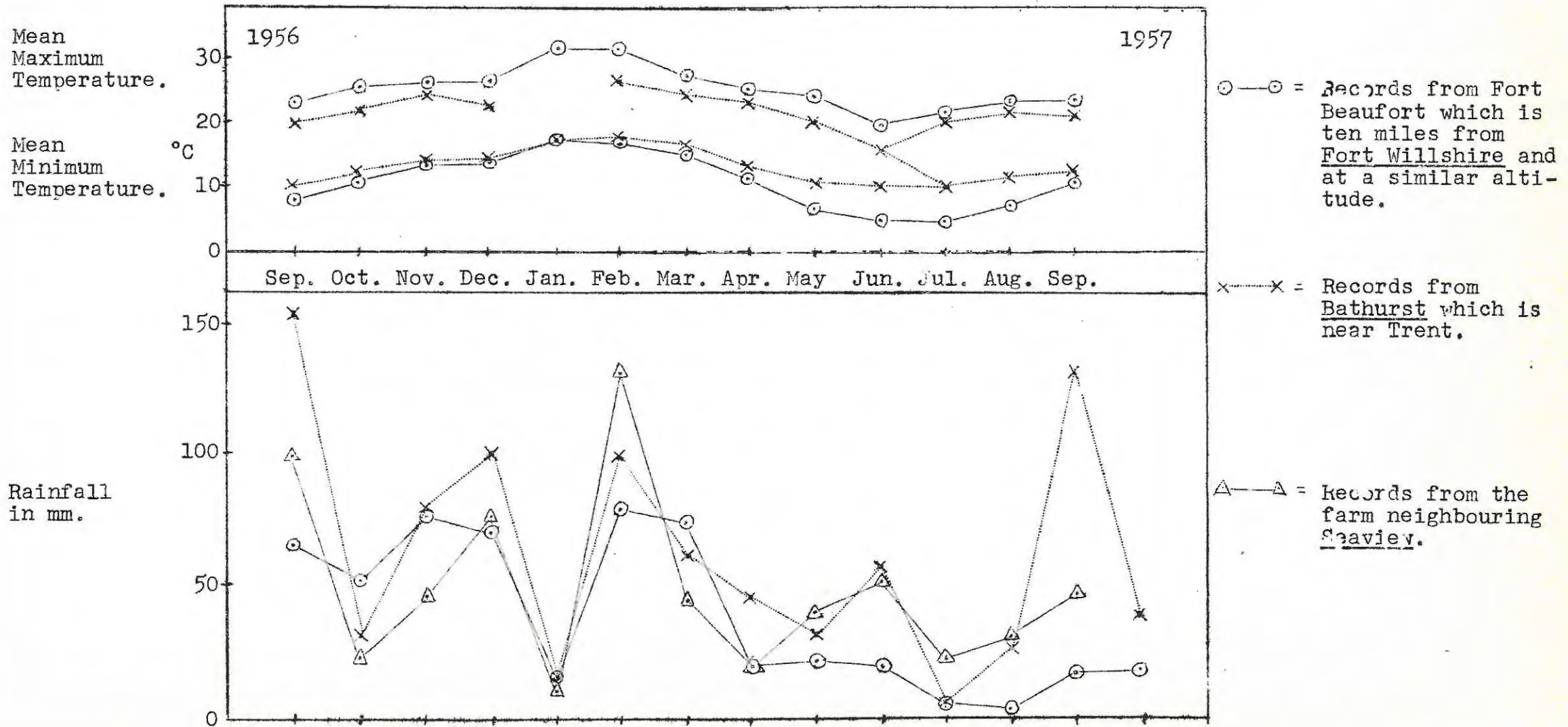


Fig. 1.

TYPES OF TOPOGRAPHY AND VEGETATION ON THE
FARMS SURVEYED FOR LARVAL TICKS.

Photo 1.

Large Valley with a River - Fort Willshire.

A south-eastern view of the Keiskama River valley, on the edge of Fort Willshire.

Photo 2.

Hollow or small valley - Trent.

The slope in the fore-ground is the north-facing rocky slope which was infested with larvae of B. decoloratus in spring (1957).





Photo 3.

Complete Overhead Cover - Seaview.

Some of the substorey vegetation in the Alexandria Forest of Camp 2-N. Numerous larvae of I. pilosus were found on such shaded vegetation both in autumn and in spring (1957).

Photo 4.

Edge of Alexandria Forest -- Seaview.

The forest fringe providing in parts Incomplete Overhead Cover. Tall - Medium-height Grass appears in the fore-ground. In autumn (1957) the forest and its fringe were found to be heavily-infested with the larvae of I. pilosus, while the more open grassy area was apparently free of clusters of these ticks.

Photo 5.

Incomplete Overhead Cover. - Fort Willshire.

A group of Euphorbia grandidans (Haw) and other vegetation providing Incomplete Overhead Cover.

Photo 6.

Incomplete Overhead Cover and Laterally-sheltered Medium-height Grass - Seaview.

The grassy area under the largest Acacia tree is provided with Incomplete Overhead Cover; the grassy areas between the trees is Laterally-sheltered.





Photo 7.

Laterally-sheltered Medium-height Grass - Trent.

Part of the 'zone of scattered bush' of Gum Trees Camp. Several clusters of larvae of B. decoloratus were found in autumn (1957) on the grass of this zone, but none on the bushes.

Photo 8.

Laterally-sheltered Short Grass. - Seaview.

Photo 9.

Tall Grass - Seaview.

Photo 10.

Tall - Medium-height Grass - Trent.

For the sake of simplicity, such grass has been placed in the same category as the Tall Grass, in the presentation of the survey data.





Photo 11.

Medium-height Grass - Trent.

In Gum Trees Camp. Part of the grassy road above the zone of scattered bush, the edge of which can be seen to the right of the picture. The

Medium-height Grass was well-infested with larval clusters of B. decoloratus in autumn (1957).

Photo 12.

Open area below the zone of scattered bush - Trent.

In Gum Trees Camp. Larval clusters were mainly near the fence which can be seen in the picture. Part of the zone of scattered bush can be seen on the left. (See also photo 7.)

Photo 13.

Short Grass - Trent.

A closer view of the grassy area near the fence (see above). At the time of the survey in autumn 1957 the grass was more short-cropped.

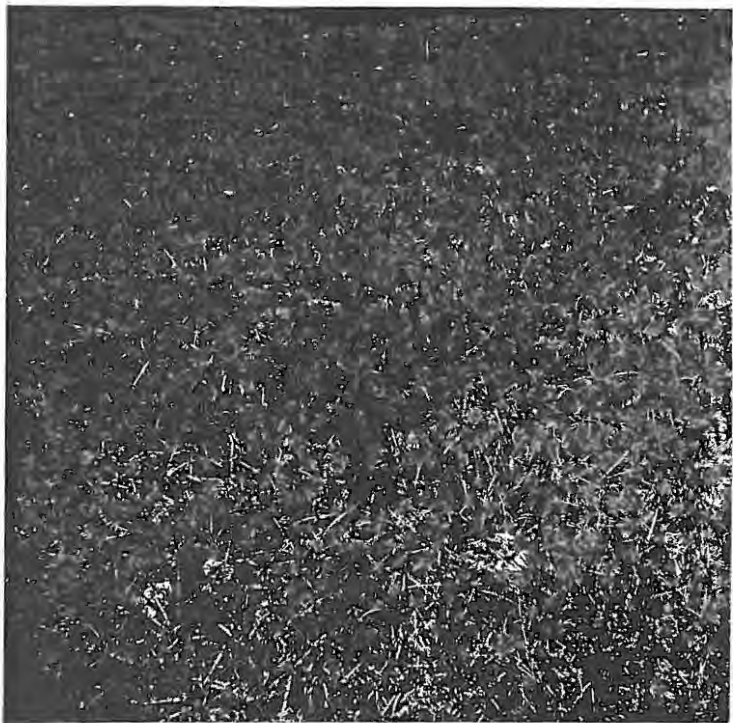




Photo 14.

Sparse Grass with Stones - Fort Willshire.

Photo 15.

Sparse Grass with No Stones - Fort Willshire.

Chapter III - STUDIES ON THE DEVELOPMENT OF LARVAL TICKS
IN MICROCLIMATICALLY DIFFERENT FIELD
SITUATIONS.

1. INTRODUCTORY REMARKS.

The surveys described in the previous chapter indicate that microclimates affect the distribution of the larval clusters of at least some of the species considered. But such surveys alone could not show whether or not the influence of microclimates is direct. To solve this problem various plots were chosen in the field, engorged female ticks were introduced into these places, and the survival and development of the ticks and their eggs were observed. Originally it was intended that the longevity of larval ticks would also be investigated but this intention had to be abandoned.

Temperature and moisture conditions are considered to be the most important climatic factors affecting the distribution of terrestrial arthropods (Wigglesworth, 1953; Uvarov, 1931). In this context the variable factor was considered to be a combination of temperature and moisture conditions, and the responses of the ticks possibly affecting the distribution of the larval clusters were considered separately to some extent, namely, as survival of engorged female ticks and their eggs, and rate of development (Mason & Langenheim, 1957).

2. THE OBSERVATION PLOTS.

For the study of direct effects of climate on the survival and development of 'pre-larval' ticks,

suitable/.....

suitable field situations had to be chosen where engorged female ticks could be introduced and subsequent events observed. At the time of choosing the plots only the autumn surveys had been made. These indicated that vegetational cover probably had a considerable effect on the distribution of larval clusters of at least some of the species considered. In autumn there was no indication of effects of topography, but nevertheless it was realised that if vegetational cover was important, it was likely that topography was as well. Thus it was decided that plots should be chosen which were different in degrees of vegetational cover, but, for the sake of simplicity, they should if possible be topographically similar.

Several fairly suitable plots were chosen in two areas, which appeared to be very different, not only in macroclimate, but also in floristic constitution. If the results from both areas could be explained in terms of direct climatic effects it would then be unlikely that other factors such as chemical differences in the soils of the several plots, were important.

It was decided that the plots would be on farms, since there they would be undisturbed by inquisitive or acquisitive humans. Furthermore, it was hoped that the farms would be tick-infested so that results obtained from introduced ticks could be checked against the natural distribution of ticks on the same farm. However, the farms eventually chosen did not fulfill this latter requirement.

Some/.....

Some difficulty was experienced in finding farmers who were willing to permit the introduction of cattle ticks onto their farms. The late Mr. William Chalmers was mainly interested in farming vegetables and kindly offered to risk the lives of his milk cows for the sake of Science. His farm was 'Mount Pleasant' (see Photo 16 and Map), which was only five miles from Grahamstown, the headquarters of the investigation.

By way of contrast, plots were also chosen at the much drier-looking farm Hounslow (see Photo 17 and Map), which was mainly a sheep farm and was owned by Mr. Gowan Dell. The Hounslow plots were about fifteen miles by road from Grahamstown.

(i) The Plots at Mount Pleasant.

The plant communities at Mount Pleasant were very varied in different parts of the farm. However, the areas shown in Photo 16 appeared to have vegetation not unlike some of that at Trent and Grandon and this seemed to be an advantage. Since this area was quite conveniently situated, it was decided that observation plots would be chosen there. Unfortunately the choice of vegetationally various plots at Mount Pleasant necessarily involved choosing topographically different places. In view of this, and of the fact that no information was available on the effects of topography on larval distribution, it was considered that no purpose would be served by detailed consideration of the survey results to aid the choice of plots. In any case, the macro-climatic differences between

Mount/.....

Mount Pleasant and the four surveyed farms would probably mean that such a detailed consideration would be wasted effort. It was decided that, in view of the existence of larval clusters of one or other species in a wide variety of vegetational cover on the surveyed farms, plots would be chosen to represent as wide a range as was possible and convenient.

At Mount Pleasant the plot affording the greatest degree of vegetational cover was in a forest, where the most conspicuous tree was Euphorbia grandidens (Haw.) This forest was on a south-facing slope. Another plot was also on a south slope, but at an altitude a few metres higher. This was in an area where there were bushes of various sizes with rather sparsely-growing grass in between. A more exposed plot was chosen, at an intermediate altitude, in a place where the ground was more level, although sloping slightly east. The soil of this plot was completely covered with short, lawn-like grass. A plot with very little vegetational cover was chosen at a slightly lower altitude on a gradual westerly slope. Here there was sparse grass and little other vegetation, although in the mornings, when shadows were long, this plot was shaded by a belt of trees a few metres to the east.

The plots were numbered in the order which seemed to represent a graded series from the usually most equable plot to the usually most extreme:

- I. Forest plot (Photos 18 and 19);
- II. Bushes of bushy plot (Photo 22);
- III. Grass of bushy plot (Photo 23);

IV/.....

IV. Dense-grass plot (Photo 25);

V. Sparse-grass plot (Photos 26 and 30).

Each of these was 7m. x 7m. except Plots II and III which formed a combined plot of 7m. x 14m.

ii) The Plots at Hounslow.

After plots had been chosen and fenced off at Mount Pleasant, suitable areas were sought at Hounslow. At this relatively dry farm an attempt was made to choose plots which would be microclimatically as similar as possible to those already chosen at Mount Pleasant.

One double-sized plot (7m. x 14m.) was in a shallow gully (Photo 20) where a large bush provided Complete Overhead Cover, and this and other nearby trees and bushes surrounded and laterally sheltered an area of about 7m. x 7m. with scanty ground cover of sparse grass and a few low shrubs. Another plot (7m. x 7m.) was chosen on a slight south slope which supported a few scattered bushes and thick, but short-cropped, tufts of grass. A third plot (7m. x 7m.) was on level ground where there was a sparse cover of stoloniferous grass. It was thought the grass of this place might at some time become dense, and thus fairly comparable with that of Plot IV at Mount Pleasant, but in fact it remained sparse throughout the investigation.

The vegetational and topographical characteristics of the Hounslow Plots suggested that they could be numbered in the following order, ranging from the least to the most extreme in climate conditions.

(Turn to Page 40)

Table 8 - Comparison of Features of the "Corresponding" Plots at Mount Pleasant and Hounslow.

		'Mount Pleasant'		'Hounslow'	
		Plot No.	Description.	Plot No.	Description.
Vegetation.	Soil.	I.	Complete to Incomplete Overhead cover provided by 7-10m. <u>Euphorbia grandidens</u> and by smaller trees.	1.	Complete to Incomplete Overhead Cover provided mainly by one large, low skirted bush, about 3m. high and 5m. wide.
			Substorey vegetation abundant but covering only part of the ground		Little substorey vegetation in parts used for ticks.
Topography.	Soil.		Much leaf debris, but under this the soil quite firm although containing much humus.		Much undecayed leaf debris most of the time. Soil beneath firm, containing relatively little humus.
			Slope fairly steep; aspect south.		On a small patch of level ground in a shallow gully worn by rain.
Vegetation.	Soil.	II/ III	Ground partly covered by two large dense bushes, two small dense bushes, several shrubs, and a considerable amount of sparsely growing grass; also a few small <u>Acacia karroo</u> (Hayne).	2.	Main ground cover sparse grass; here and there lowgrowing and some larger small-leaved plants. Area sheltered almost completely from wind on all sides. Narrow gaps in the barricade of bush to the North-west & South-west
			Much leaf debris under bushes. Soil firm especially away from bush		Little debris. Soil firm.
Topography.	Soil.		Aspect south. Slope steep.		On level ground immediately beside Plot 1.

		'Mount Pleasant'		'Hounslow'	
		Plot No.	Description.	Plot No.	Description.
Vegetation	IV.		Ground covered completely with densely growing grass, Short to Medium Height. Sheltered from wind to a slight degree by trees on south side.	3.	Main vegetation wide tufts of grass or other low-growing plants, 30cm. or more apart. Sheltered from wind to a slight degree on all sides by scattered bushes.
			Much grass and manure debris in soil, which was loose to the depth of several centimeters in some parts. Surface soil firm in some places.		Soil firm, but overlaid with much sheep faeces in various stages of decomposition.
Soil			Fairly level ground sloping slightly to the East in part.		Slope steeper; aspect southerly.
Topography	V.		In part used, main vegetation small tufts of grass about 15 cms apart from one another. Protected laterally to some extent by tall trees to the East and shorter vegetation to the South.	4.	Stoloniferous grass sparse during the investigation.
Vegetation			Soil very firm. Little debris. Some small stones here and there on the soil surface.		Little debris. Soil loose and dusty in a 1 cm. layer over firmer soil. Many small chips of slate about.
Soil			Slope slight; aspect westerly.		On level ground.
Topography					

1. Under the large bush of the gully plot (Photo 21);
2. The laterally-shaded part of the gully plot (Photo 24);
3. The tufted grass plot on the slight southern slope (Photo 28);
4. The level plot with very sparse grass cover (Photo 27).

Details of the characteristics of the plots on the two farms are compared on Pages 38 and 39 and photographs of them are shown at the end of the chapter. The Mount Pleasant plots were photographed while still in use, but some of the plots at Hounslow were photographed some months after the investigations at that farm, when the fences enclosing the plots had already been dismantled.

3. THE CLIMATIC CONDITIONS.

(i) Methods of Measurement. (Photos 31 to 34).

To check the assumption about the climate relations between plots, it was necessary to make some measurements. No real effort was made to record specific factors in the environments of the ticks introduced, although it was hoped that the climate data would provide some information in this regard. The plots were visited once a week, almost always in the afternoon.

Some idea of moisture relations between plots was obtained by the following means:-

Raingauges. On each of the two farms a standard raingauge and an automatic gauge were erected in the plot which had fairly level ground and low vegetation, namely/.....

namely Plot IV at Mount Pleasant and Plot 4 at Hounslow. 'Bottle Funnels'. Nine similar funnels were made of galvanized iron. Each plot was provided with a funnel in a large bottle, which was buried in the soil so that the upper rim of the funnel was about 30 cms. above the soil surface. If the bottles had not overflowed, some idea was obtained of the relative amount of rain directly reaching the low vegetation and soil of each plot.

Piché Evaporimeters (Piché, 1872), were constructed and placed in the various plots, the evaporating discs being about 8 cms. above the soil surface. Evaporation could be measured along the length of the water-containing column and compared in the different plots of a farm (February - May 1958). The readings obtained from the two farms were not comparable because the bore of the glass tubes of the evaporimeters at Mount Pleasant was different to that of the tubing used for Hounslow and I omitted to measure the difference.

Anemometer. In October and November, 1957 a few readings of wind speed were made in the different plots with the aid of a Cup Anemometer. On each occasion one to three series of measurements were made in rapid succession in the several plots.

Soil Samples, were collected each week from the plots from October 1957 to the beginning of March, 1958 so that percentage saturation of the surface soils could be compared at least intermittently. The samples were collected in 7.5 cm. x 2.5 cm. glass tubes, stoppered with corks which had been soaked in hot wax to render them more waterproof. The samples were weighed/.....

weighed before and after oven-drying for 24 hours at 100°C, and the water content was calculated. Since the soils of the several plots were very different, their absolute water content was of less interest than the percentage saturation. This latter was calculated by comparing the water content with that of samples of plot soils which had been saturated with water in the laboratory and allowed to drain for 5.5 hours (no evaporation permitted). Correction was made for differences in quantity (dry weight) of soil collected in different samples from the same plot.

Temperature relations between plots were assessed as follows:-

Maximum and Minimum Thermometers. From December, 1957 till the end of the investigation, temperatures in the plots of both farms were measured by means of separate maximum and minimum thermometers. These were supported about 5.0 cms. above the ground and shaded by wooden screens. In January some of the maximum thermometers were transferred to the soil, where they were housed in galvanized iron pipes stoppered at both ends with corks (Johnson & Davies, 1927). The pipes were placed horizontally and covered with about 1 cm. of soil. The maximum temperatures recorded in the soil provided a more contrasting picture of heat relations between plots than did the air temperatures shown on the thermometers above the soil. Burial of minimum thermometers was also attempted but this had a bad effect on the alcohol columns of these instruments.

Further information was obtained about the climates of Mount Pleasant and Hounslow from two Negretti and Zambra/.....

Zambra air thermohygrographs. These instruments were not similarly housed on the two farms; the one at Hounslow was placed on the veranda of an unused homestead, which was by day one of the coolest places on the farm, while at Mount Pleasant the instrument was placed in a small fowl house where the maximum air temperatures were sometimes similar to those of the exposed plots on that farm (Appendix) On the other hand, at both farms, the minimum air temperatures recorded by the thermohygrographs and the thermometers in the plots were similar.

The temperatures recorded on the thermohygrographs have been used to provide a picture of seasonal changes in the temperature regime of Hounslow and Mount Pleasant. The relative humidities recorded have not been used since the information obtained from the raingauges was adequate.

Thermohygrographs and raingauges were not available at the start of the plot investigations, and thus some use has been made of data recorded at the Veterinary Station at Grahamstown. The climate of Grahamstown was similar to that of Mount Pleasant, but less similar to the Hounslow climate.

The records of micro-climatic conditions did not prove to be entirely adequate since the measurements were not made frequently enough or for long enough periods during the investigation. Nevertheless, it was found possible to make the somewhat cautious statements about climate relations which are presented in the following two sections. (See Appendix for details).

(ii)/.....

(ii) Climate Relations between Plots at Hounslow.
High Temperatures.

Maximum air and soil temperatures at Hounslow were recorded mainly in plots 1, 3 and 4. The indications obtained are presented below.

Plot 1 was always the coolest plot in the day time, until some heavy rain necessitated a change of position to slightly higher and drier ground within the same plot. The move was made on 23rd January 1958 and, once the effects of the heavy rains had worn off, i.e. when the soil was no longer unusually wet, the new Plot 1 situation apparently became one of the hottest plots during the day. The maximum temperature relations between Plots 3 and 4 were much less distinct, but Plot 3 almost invariably showed a lower maximum temperature than did Plot 4. The few maximum temperature records made in Plot 2 late in the investigation indicated that, during the day, this was one of the coolest of the Hounslow plots at least at a cool, fairly damp time of year.

It seems that the Hounslow plots had been graded from the usually coolest to the usually hottest by day, although the temperature relations of Plot 2 are less definite than those of the others since very few records were made in this plot.

Low Temperatures.

Minimum air temperatures were recorded also mainly in Plots 1, 3 and 4, and these indicated that at night Plot 4 was usually the coldest and Plot 1 was frequently the warmest of the three. After rain Plot 1 was sometimes cooler at night than was Plot 3. A

few/.....

few records of minimum temperatures recorded in Plot 2 indicated that this plot was sometimes as cold or colder than any of the other three plots. This was probably partly because of the low-lying situation of Plot 2.

Moisture.

The percentage soil saturation values for the different plots were not strictly comparable because of the undoubted differences in the physical properties of the soils (Richards, 1928). Nevertheless, comparison of the soil saturation data from the different plots appears to provide a fairly comprehensible picture.

At Hounslow, Plots 1 and 2 were usually wetter than Plots 3 and 4. This was especially apparent some days after rain, when much water had been lost from the surface soils of the two plots which were more exposed and also situated higher up.

Plot 1 was usually moister than Plot 2, until the change of the utilized part of Plot 1 to a higher and drier position, when ticks and thermometers were threatened by rainwaters; then Plot 2 seemed to be usually more humid.

In dry weather, Plot 4, the most exposed, was usually slightly drier than Plot 3, but sometimes, not many days after rain, the relationship was reversed, probably because although Plot 3 had more vegetational cover, it was on sloping ground, whereas Plot 4 was on level ground in a slightly depressed area.

Thus it seemed that in the dry seasons the plots at Hounslow were graded from the most to the least

humid/.....

humid, but that in wetter periods, for one reason or another the moisture relations were somewhat different.

(iii) Climate Relations between Plots at Mount Pleasant.
High Temperatures.

Maximum air and soil temperature records were made mainly in Plots I, IV and V and these indicate that Plot I was usually the coolest by day, which was to be expected. It had been thought that Plot V would be hotter than Plot IV but this was not the case. Perhaps Plot V was usually cooler because it was shaded by trees for a considerable part of the morning.

A few records of maximum temperatures made in Plots II and III indicated that by day Plot II was warmer than Plot I but cooler than Plots IV and V, while Plot III was frequently the hottest of all plots. The last indication is doubtless related to the relatively dry nature of Plot III as mentioned below.

The difference in the maxima of several plots at Mount Pleasant became less and less as the cooler weather advanced, until finally the more exposed plots were cooler than Plot I, but by this time the tick investigations were virtually at an end.

Low Temperatures.

Minimum air temperatures were recorded only in Plots I, IV and V, and these indicate that of the three Plot I was usually the warmest at night and Plot IV usually the coolest. Thus Plot IV, usually showed the highest and the lowest temperatures.

the/.....

Moisture.

The soil saturation data, which are roughly comparable between plots, indicate that the moisture relations of the Mount Pleasant plots were very variable. This was probably mainly because: (a) the exposed plots were most exposed to rain, which fell quite frequently on this farm: (b) Plots II and III were on a steep slope, where rainwater must have drained away more quickly than was the case in the more level plots I, IV and V; (c) the evaporation from the sheltered plots tended to be less than in the exposed plots; and (d) the vegetation in the plots did not remain the same, especially in Plot IV where the grass was sometimes short, sometimes medium height, sometimes green and sometimes dry and yellow.

Despite the complications, it can be stated that the following seemed to be usually the case:-

- Plot I - among the wetter plots;
- Plot II - probably wetter than the more exposed plots;
- Plot III - among the drier plots;
- Plot IV - wetter than Plot V, unless grass 'dry and yellow';
- Plot V - drier than Plot IV unless grass of the latter 'dry and yellow',

(iv) Climate Relations between Farms. '

In this context little purpose would be served by a comparison of macroclimatic conditions such as might be recorded in a Stevenson's Screen, although it is true that if one wished to generalise about the

distribution/.....

distribution of ticks in areas other than those investigated in detail, such records would be essential. This type of generalisation was not required from the present investigation and thus in comparing the two farms here the only concern is to consider the climate relations between 'corresponding plots' (cf Table 8). In this it is necessary to bear in mind that the plots of the two farms were not visited on the same days.

High Temperatures.

Plots 1/I. Plot I was warmer by day, but later Plot 1 was warmer, after the change of the used part of Plot 1, and when the effects of rains had largely worn off (cf 3 ii);

Plots 3/III. Plot III was warmer, according to the small amount of data available;

Plots 3/IV. Plot IV was warmer until towards the end of March, when Plot 3 became apparently warmer, probably because the general temperatures of Mount Pleasant were dropping while those at Hounslow remained at a relatively high level; also the vegetational cover of Plot 3 was less than at Plot IV;

Plots 4/V. Plot 4 was probably usually the warmer plot, but the picture is rather obscured by differences shown in the air temperature and soil temperature relations.

Low Temperatures.

The Hounslow plots appeared to be colder at night than the corresponding plots at Mount Pleasant. On at least/.....

least one occasion the temperature appeared to be considerably lower, namely when Mount Pleasant was visited on 2nd December and Hounslow was visited two days later. Then all plots at Mount Pleasant showed minimum air temperatures of at least 10°C, while the Hounslow plots, during a similar period, had minima of 3°C and less.

Moisture.

The soil saturation values indicated that the Hounslow plots 1, 3 and 4 were usually drier than the corresponding plots at Mount Pleasant, as one would expect from the rainfall data. This was apparently not the case for Plot 2. The moisture relations between the low-lying Plot 2 and the sloping Plot III appeared to be very variable.

4. THE TICKS.

(i) Sources of Engorged Female Ticks.

Some attempts were made to rear large numbers of engorged female ticks in the laboratory, on the ears of rabbits, but this was not practicable, and thus the ticks had to be collected from hosts in the field. Since sufficient numbers of the ticks could not be found within one small area, they were collected from several different places in the Eastern Cape Province, - but most of them came from cattle in the vicinity of Grahamstown or of the town of Bathurst. The ticks were plucked from their hosts usually just before the cattle were dipped or sprayed with acaricide, i.e. at least a week after they had last been treated for parasites.

The engorged female ticks were placed together

in/.....

in large glass tubes stoppered with cotton-wool, and were kept on the laboratory bench until they were introduced into the plots at Mount Pleasant and Hounslow. Ticks collected on a certain date at one dipping place or farm constituted a tick 'batch', which was shared out between the plots, if possible on both farms. This often meant that each plot had a very small sample of a batch, particularly during the cooler months of the year when it was difficult to obtain large numbers of ticks.

Ticks introduced onto the two farms were always introduced on different days, since the transport facilities available did not permit visits to both farms on one day. On each farm, introduction of ticks of a batch was effected within the space of one to three hours, usually in the afternoon.

(ii) Methods of Confining Ticks.

It was necessary to confine the engorged females in some way since they were sometimes inclined to walk. To prevent the loss of the ticks 'wards' were designed (Photo. 30) to confine them to an area of 23cm. x 23cm. This arrangement was not satisfactory because the engorged females showed a tendency to burrow under the walls of the ward and in this way some of them 'escaped'. Also in plots such as Plot IV (Mount Pleasant) it was difficult to find ticks in a ward because the grassy ground cover was dense.

Eventually it was decided that each engorged female tick and her eggs would be confined to a

glass/.....

glass tube, without a bottom so that rain water would not accumulate, but with a base and a cap of organdi or terylene fabric.

The four species of ticks differed considerably in size and the tubes containing them also varied depending on the girth of the tick. Thus I. pilosus and B. decoloratus were placed in small tubes of about 1 cm. in diameter and 2.5 cm. in height; A. hebraeum went into large tubes, about 2.5 cm. x 4.0 cm; and tubes for the females of R. evertsi were intermediate in size being 1.5 cm. x 3.0 cm. The thickness of the tube glass was similar in each case, except that some tubes used for R. evertsi had walls about twice as thick as the others.

The tubes were placed upright in a shallow hole in the soil and just covered usually with soil or plant debris. Since several tubes were introduced at one time, the tubes of a batch were buried in groups as illustrated in Photo 30.

From the practical point of view the tubes were on the whole satisfactory for confining ticks. If the fabric cap of a tube was removed, the contained females or eggs could be tipped into the hand and closely examined.

Only the tube data are considered here since comparison of these data and those obtained from ticks confined in wards showed some discrepancy. This suggests the possibility that the results obtained from the tubes were 'unnatural'. However, it seems unlikely that tube conditions could be so unnatural as to invalidate the results of the

present/.....

present investigation.

(iii) Examination of Ticks.

The ticks in the tubes were examined once a week, and each time notes were made on features of the females and eggs which might have had some bearing on the survival or rate of development of the pre-larval stages.

Survival.

If a female tick was active it was, of course, alive. When inactive, it might have been dead, but if there was any doubt, the tick was replaced in its tube and left until it was clearly dead. In this way several 'dead' ticks were permitted to come to life. On cold days breathing closely on an inactive female sometimes induced it to show signs of life. Obvious indications of death of the engorged females were, (a) hard dryness of the whole body or brittleness of the limbs; (b) dark discolouration of the whole body; and (c) mouldiness or other signs of decay.

It was more difficult to ascertain whether or not the eggs were alive. Obvious shrivelling indicated death. Less obvious signs of ill-health were also noted, but, except in the early stages of the investigation, 'sick' eggs were left in the plots and examined every week for as long as there was a possibility of their being alive.

Rate of Development.

Several features indicative of developmental processes were noted and these are listed below.

(a) The

(a) The onset of oviposition marked the end of the 'pre-oviposition period' (Hitchcock, 1955 b).

(b) The external appearance of the eggs provided some indication of the stage of development of the embryo within. At a fairly late stage of development, a white speck becomes visible on each egg, and such were referred to as 'speckled' eggs. The speck on a tick egg is the visible sign of an accumulation of uric acid or guanine at the base of the malpighian tubules of the developing larva (Arthur, 1948).

(c) Hatching was the last step in the development of the larvae to be consistently considered. Larvae of almost all groups which hatched, also managed to tan their cuticles successfully.

5. THE EFFECTS OF CLIMATE ON RATE OF DEVELOPMENT.

Reference to Figures 2 and 3 will show that, on the whole, development was faster in the more exposed plots. Furthermore, at Mount Pleasant it was evident that development was quicker during the warmer months. In fact examination of the exceptions to the rule shows that most of the data were compatible with the notion that development was faster in the places which were in the main warmer (Hitchcock, 1955 b). Some of the data are considered specifically below.

(i) Examples of Faster Development in 'Warmer' Situations.

(a) Of the batch of B. decoloratus introduced into the Mount Pleasant plots in January, 1958, the group in Plot III commenced oviposition sooner than those in the more exposed Plot IV. This was not surprising since

Plot/.....

Plot III was known to vary in its climatic relations with respect to Plots IV and V and was sometimes evidently the warmest plot during the day.

(b) Of a batch of B. decoloratus introduced into the Hounslow plots in March 1958, those in Plot 1 laid eggs before the females in the more exposed types of plot. The probable explanation for this is that the section of Plot 1 used in the latter part of the investigation at Hounslow was sometimes warmer

Table 9.

Date	Development of <u>B. decoloratus</u> in	
	Plot I (Mt.P.)	Plot 1 (Houns).
15/I	Introd.	
16/I		Introd.
19/I	No eggs	
33/I		EGGS
26/I	EGGS	
30/I		EGGS
2/II	EGGS	
6/II		EGGS
9/II	EGGS	
13/II		EGGS
16/II	Speckled	
20/II		Speckled
23/II	Speckled	
27/II		Speckled
2/III	Speckled	
6/III		Speckled
9/III	LARVAE	
14/III		LARVAE

than the more exposed plots, - even during the day.

(c) The picture obtained from the comparison of data for 'corresponding plots' of the two farms can be explained mainly in the same terms.

A batch of B. decoloratus was collected at Grahamstown on 13th January, 1958, and was introduced into the Mount Pleasant plots on 15th, and to Hounslow on 16th January. As can be seen in Table 9 those in the most sheltered plot of each farm developed at about the same rate. The climate data suggest that the

maximum/.....

maximum temperatures in Plots I (Mount Pleasant) and 1 (Hounslow) were similar, although the minimum temperatures were lower at Hounslow. A different result was obtained when a second batch of the same species, collected in Grahamstown on 3rd February, was introduced into the higher and drier part of Plot 1 (Hounslow) but into the usual type of place in the corresponding plot at Mount Pleasant. Table 10 shows the striking difference in the developmental rates in these two plots, which, in view of the earlier result, is another demonstration of faster development in the higher and drier part of Plot 1 at Hounslow (see (b) above).

Table 10.

Date	<u>B. decoloratus</u> (3rd February Batch).		<u>R. evertsi</u> (21st January Batch).	
	Plot I	Plot 1	Plot I	Plot 1
22/I			Introduced	
23/I				Introduced
26/I			No eggs.	
30/I				EGGS
2/II			EGGS	
4/II	Introduced			
6/II		Introduced		EGGS
9/II	No eggs		EGGS	
13/II		EGGS		EGGS
16/II	EGGS		EGGS	
20/II		EGGS		EGGS
23/II	EGGS		EGGS	
27/II		EGGS		Speckled
2/III	EGGS		Speckled	
6/III		Speckled		Speckled
9/III	EGGS		Speckled	
14/III		Speckled		LARVAE
16/III	EGGS		Speckled	
21/III		LARVAE		
23/III	Speckled		Speckled	
28/III				
30/III	Speckled		Speckled	
4/IV				
6/IV	Speckled		LARVAE	
11/IV				
13/IV	Speckled			
18/IV				
20/IV	LARVAE			

A similar result (also shown in Table 10) was obtained for a batch of R. evertsi which was collected at the Bathurst sprayrace on 21st January. However in this case the difference in rate of development in Plots I and 1 was only evident in the speckled stage of the eggs.

(ii) Example of Slower Development in a 'Warmer' Situation.

When the rate of development differed in Plots IV and V, both at cool and at warm times of the year, it was slower in Plot IV than in Plot V, despite the usually warmer diurnal temperatures of the former. Possibly related to this is the fact that comparable ticks of B. decoloratus and R. evertsi, which were introduced onto the two farms in February, developed faster in Plot 3 of Hounslow than in warmer corresponding Plot IV. The relevant data for the between-farm comparison are shown in Table 11.

There are several possible explanations, the simpler of which are the following:-

(a) Although the weekly maximum temperatures in Plot IV were mainly higher than in Plot V or 3, the average temperatures may have been lower;

(b) The average temperatures may have been similar in all three plots, but the temperature differences at the lower part of the range may have mainly determined the differences in developmental rates. The recorded temperatures are not very useful in this connection since they show only the very high temperatures, at which level temperature differences may be insignificant (cf MacLeod 1934), and the very

low/.....

Table 11.

Date	<u>B. decoloratus</u>			<u>R. evertsi</u>		
	Plot IV	Plot V	Plot 3	Plot IV	Plot V	Plot 3
19/II	Intro-duced	Intro-duced		Intro-duced	Intro-duced	
20/II			Intro-duced			Intro-duced
23/II	No eggs	No eggs		No eggs	No eggs	
27/II			EGGS			EGGS
2/III	EGGS	EGGS		EGGS	EGGS	
6/III			EGGS			EGGS
9/III	EGGS	EGGS		EGGS	EGGS	
14/III			Speckled			EGGS
16/III	EGGS	EGGS		EGGS	EGGS	
21/III			Some dead			EGGS
23/III	EGGS	Speckled		EGGS	Speckled	
28/III						Speckled
30/III	Speckled	Speckled		Speckled	Speckled	
4/IV						?
6/IV	Speckled	LARVAE		Speckled	Speckled	
11/IV						LARVAE
13/IV	LARVAE			Speckled	Speckled	
18/IV						
20/IV				Speckled	LARVAE	
25/IV						
27/IV				Speckled		
2/V						
4/V				LARVAE		

low temperatures, at which probably no development occurs at all (MacLeod, 1934; Hitchcock, 1955 b).

(c) Greater temperature fluctuations in Plot IV (Table 12) may have delayed development more than did the fluctuations in the Plots V and 3. (MacLeod, 1934);

Plot 4/.....

Plot 4 frequently showed greater temperature extremes than did Plot IV, but in the Hounslow plot ticks also died very rapidly and thus there is insufficient data for comparison of developmental rates in Plots IV and 4.

Table 12. - Comparison of Temperature Fluctuations in Plots IV and 3.

Date	Plot IV			Plot 3		
	Soil Max.	Air Min.	Difference.	Soil Max.	Air Min.	Difference.
20/II				55.5°C	10.4°C	45.1
23/II	48.9°C	11.1°C	37.8			
27/II				48.6	12.6	36.0
2/III	52.5	13.2	39.3			
6/III				50.4	8.0	42.4
9/III	49.8	10.25	39.55			
14/III				48.9	13.9	35.0
16/III	57.5	12.5	45.0			
21/III				47.6	12.6	35.0
23/III	49.8	13.6	36.2			
28/III				39.4	8.2	31.2
6/IV	40.75	8.9	31.85			
11/IV				42.6	8.2	34.4

(From 20th February - 6th March the soil thermometer in Plot 3 was inadvertently shaded by the thermometer screen for part of the hot time of the day. It is possible that higher maxima might have been recorded on these days had the thermometer been more exposed).

6. EFFECTS OF CLIMATE ON THE SURVIVAL OF PRELARVAL TICKS.

The data in Figures 2 and 3 show that on some occasions prelarval ticks of different batches, and even of different species, died between one weekly examination and the next. It seems probably that such deaths were caused by conditions which were suddenly unfavourable in the week during which the several deaths occurred. On the other hand, deaths sometimes did not involve all stages and ages of ticks in a plot, and when survival of prelarval stages was compared between plots it was found that such deaths usually occurred relatively rapidly at one end of the range of plot microclimates and less and less soon after the females had been introduced into the plots towards the other end of the range. In these cases deaths may have been caused by conditions which were cumulatively unfavourable over several weeks. However it is possible too that such deaths were sudden; for instance when in one plot only some stages die this may be because of physiological differences between different stages; and when prelarval ticks show graded duration of survival in the several plots this may be because conditions are first intolerable at one end of the range of situations, but gradually the microclimates of more and more plots become as extreme as the first, for instance because of desiccation of vegetation during a drought.

In this section the deaths of prelarval ticks are divided into those which were probably sudden and these possibly more gradual. Also deaths occurring under hot and dry conditions are considered separately to those occurring under wet and cool conditions.

(i) Probably Sudden Deaths under Hot/Dry Conditions.

- (a) At Mount Pleasant after a rainy spring (1957) conditions became drier, until during the second

half/.....

half of November, no rain fell at all. At the same time temperatures were rising, and the grass in Plots IV and V became dry and yellow. The November drought had a striking effect on the survival of the ticks and eggs in the plots; stages from batches introduced at very different times died within a fortnight of one another, (see Fig. 2). It seemed that during this drought prelarval ticks were being killed within a short period irrespective of species, stage of development, and differing environmental histories. This involved all the stages which were in plots other than Plot I, i.e. mainly those in Plots IV and V. In Plot I eggs of I. pilosus, B. decoloratus and R. evertsi, which had been in the plot for a long period of several months, did not survive the drought, whereas, in the case of all three species, eggs of the more recently introduced batches did survive and hatched into larvae during or after the dry period. Thus, in the well-shaded situation, environmental history probably was of significance in determining whether or not the prelarval ticks would survive.

(b) At about the same time there was an even more serious drought at Hounslow, and there the picture of survival and death of the prelarval ticks was similar, although most of the tick batches concerned had been introduced at very different times to those at Mount Pleasant. The ticks in the Hounslow plots during the November drought were mostly introduced in the rainless period.

Almost/.....

Almost all those in the exposed plots died within a week of being placed in these situations. Those in Plot 1 survived the dry conditions but most were removed by predators. One engorged female of I. pilosus in Plot 1 escaped the ravages of the predators, and laid eggs which eventually hatched some weeks after the drought was over. If female ticks of I. pilosus had been introduced at an earlier stage of the dry period, these might not have survived the extremes of climate.

(c) In January, 1958 conditions at Mount Pleasant were on the whole quite wet, but towards the end of that month the rainfall dropped to a low level and for the first half of February remained relatively low. At the same time average daily maximum and minimum temperatures were more or less at peak summer level, the vegetation in all plots was wilting, and the grass in Plot IV was becoming yellow. Then, in the middle of February there was a heavy rain, but it seemed that before this down-pour all the prelarval ticks in the more exposed Plots IV and V were dead. These included:- engorged females of A. hebraeum; engorged females and unspeckled eggs of R. evertsi; unspeckled and speckled eggs of B. decoloratus; and engorged females of I. pilosus. On the other hand, prelarval stages of all four species in Plots I and II were mainly not adversely affected by the hot, dry period, the exception being those of I. pilosus in Plot II.

(d) At the same time there was at Hounslow a complete drought, which followed a period of heavy rains. Some of the ticks died in the exposed plots while/...

while almost all in Plot 1 survived, the exception again being I. pilosus.

(e) After a week of high rainfall in the second half of February there was another dry spell at Hounslow during which there were further deaths in the exposed plots, although some prelarval ticks survived in these places, as well as in Plot 1.

The plots which were hot and dry were also those which were at night the coolest. Thus, one must consider the possibility of ticks dying from extreme cold in these places, but in fact there were no indications that any of the more sudden deaths could have been due to low temperature alone. The lowest minimum temperatures recorded were of the week-ending 4th December, 1957 at Hounslow, when Plot 1 had a minimum air temperature of 3.0°C and the more exposed plots showed slightly lower temperatures. At the time a female of I. pilosus, and eggs of B. decoloratus and R. evertsi, all in Plot 1, were apparently not adversely affected.

(ii) Possibly Gradual Deaths under Hot/Dry Conditions.

In considering the 'possibly more gradual deaths' an attempt has been made to find some correlation between climatic conditions on the one hand, and the duration of survival of prelarval ticks on the other. A glance at the results obtained for Mount Pleasant (Fig 2) will show that the prelarval stages of I. pilosus,

B. decoloratus/.....

B. decoloratus and R. evertsi, tended to die more quickly if introduced into the plots during the warmer months. There are also indications that in January and February deaths occurred more quickly in the warmer plots of both farms.

Two aspects of the Mount Pleasant data of this period need some comment. Firstly, it was not surprising that ticks sometimes died more quickly in Plot III than in the other exposed plots, since Plot III was sometimes the hottest plot at Mount Pleasant. Secondly, it appears that deaths of female ticks occurred more quickly in Plot V than in the usually warmer Plot IV. Perhaps this is because desiccation of the ticks was less in Plot IV owing to the complete cover of grass there, but one would think that the higher temperatures of this plot would offset the advantage of the greater protection from air movement. On the other hand it is possible that the soil of Plot V was mainly responsible for the difference in duration of survival in Plots IV and V. Lees (1947) finds that if the cuticle of a tick is rubbed with an inert dust, evaporation is greatly increased, and Hitchcock (1955 b) finds that even dusting with soil increases water loss in the females of B. microplus. During the present investigation it was noticed that the ticks in Plot V were frequently coated with exceedingly fine dust, which had found its way through the terylene-capped ends of the tick tubes. Often some of this coating was manually rubbed away so that the appearance and colour of the ticks could be noted.

Thus/.....

Thus many of the ticks in Plot V were both dusted and abraded, and consequently they may have lost water more rapidly than did the ticks in Plot IV.

At Hounslow there seemed to be a tendency for ticks in Plot 2 to die more quickly than others on that farm. This is probably not linked with low humidity or high temperature, since this plot appeared to be relatively cool and moist and was also sheltered from winds. Because few climate records were made in Plot 2 it is difficult to speculate about reasons for its unfavourableness. There were slight indications that it became increasingly unfavourable as the cool season advanced.

(iii) Probably Sudden Death under Cool/Moist Conditions.

Perhaps the egg-mass of a single individual tick is not worthy of special mention, but the only indication of possible sudden effects of cool and moist conditions on the survival of prelarval ticks involved a single egg-mass of R. evertsi. The eggs were in Plot I at Mount Pleasant, and towards the end of April 1958, they became speckled. In the first week of May they were all dead and mouldy. The eggs had shown no signs of 'sickness' and had died in a week of heavy rains and when temperatures were low. It seems possible that they were killed by high moisture.

(iv) Possibly Gradual Deaths in Cool/Moist Conditions.

The picture for the first five months of the investigation at Mount Pleasant, when conditions were moist and cool, appears to be somewhat 'ragged',

perhaps /.....

perhaps mainly because of the small sizes of samples at that time. Nevertheless, the first batch of B. decoloratus to be introduced into the plots provides a result which may be significant. The batch was placed in the plots in June 1957, but those in Plots II and III were soon eaten by predators. The fates of the remaining ticks of the batch suggest that the more sheltered the plot, the sooner did death overcome the prelarval stages there. The ticks in Plot V reached the larval stage, but before this, the unspckled eggs in Plot IV had died, and at an even earlier stage, the female ticks in Plot I were dead before they had laid any eggs. The prelarval ticks in Plots I and IV may have died because of prolonged subjection to low temperatures or high humidities, perhaps both (cf Snowball, 1957).

7. COMPARISON OF SURVEY AND PLOT RESULTS. (Table 13)

At this stage it is of interest to ascertain to what extent the plot data tally with the results obtained from the surveys. Comparison of the two types of information is difficult for several reasons. Firstly, the data obtained in spring relate to different months since engorged female ticks were not introduced into the plots sufficiently early in winter to show whether or not larval clusters would appear in these places in August or September 1957, when the surveys were made. Secondly the autumnal data for plots and surveys were obtained in different years. Thirdly, some of the discrepancies between the two types of information may have been merely because the longevity of larvae was not investigated. Despite these drawbacks

some/.....

Table 13 - Comparison of Survey and Plot Results.

Species	Plots at Mount Pleasant								Comparable Types of Vegetation Surveyed(1957)			
	1958				1957				1	4	6	9
Month	I	III	IV	V	I	III	IV	V				
<u>I.pilosus</u>												
Aug.									+	+	+	
Sep												
Oct												
Nov												
Dec					+	-	-	-				
Jan												
Feb												
Mar	+	-	-	-								
Apr	+	-	-	-					+	-	-	-
<u>B.decoloratus.</u>												
Aug											+	+
Sep											+	
Oct					-		-	+				
Nov					-		-	-				
Dec					+		-	-				
Jan												
Feb												
Mar	+	-	-	-					-	+	+	+
Apr	+	+	+	+							+	+

Types of Vegetational Cover.

1. Complete Overhead Cover;
4. Incomplete Overhead Cover;
6. Medium-height Grass;
9. Sparse Grass with No Stones

Symbols.

- = No larvae.
+ = Larval Clusters present.

some possibly significant points emerge from a comparison of data obtained in the Mount Pleasant plots with results of the surveys.

I. pilosus.

The survey data show that, in autumn, clusters of this species were found only in situations with Complete or Incomplete Overhead Cover. This result was obtained at Seaview in April 1957 and it tallies with the fact that at Mount Pleasant these larvae were to be found only in the plots with similar type of vegetational cover, because the prelarval stages could not survive in the more exposed places.

In the spring survey of Seaview, in August 1957, larval clusters of I. pilosus were found in exposed, as well as in shaded situations. Perhaps if engorged female ticks had been introduced into observation plots in autumn, say in March, April or May, some larvae would have appeared in these plots in August or thereabouts.

B. decoloratus.

The survey and plot data agree in suggesting that during winter most situations are unfavourable for the development of larvae of this species, and that in spring larvae will appear first in the warmest places.

On the other hand, two points of disagreement emerge from comparison of data relating to the autumn distribution of larval clusters. (a) In February/March, unshaded grassy situations yielded larval clusters in the Trent surveys, whereas in the same months of the following year, such places at Mount Pleasant appeared to be unfavourable to the survival of the prelarval stages.

(b) From/.....

(b) From February to May the well-sheltered plots at Mount Pleasant were favourable, whereas no larval clusters of B. decoloratus were found in similar situations surveyed on four farms during the same months of the previous year, - not even in a fairly well-infested camp at Trent.

The differences in the February rainfalls of 1957 and 1958 may be the cause of the first discrepancy. The rainfall at Trent in February 1957 was 100 mm, while at Mount Pleasant in the following February it was only 56 mm. Perhaps in the warm, wet conditions immediately preceding the autumnal survey of Trent, larval clusters could develop in the unshaded places, whereas at Mount Pleasant in the warm but drier weather at a similar time of year the larvae could develop only in the more sheltered situations.

The explanation of the second discrepancy is more obscure. The well-shaded places at Trent, in which no clusters of the larvae could be found, were probably warm and damp in the weeks preceding the autumnal surveys of that farm, but the plot investigations provided no data to suggest that such conditions are unfavourable to the survival or development of the larvae. Perhaps the explanation lies in the climate of January.

Figure 1 shows that there was a drought in January 1957, which was apparently more severe than that occurring during the plot investigations in November/December of the same year. During the latter drought all prelarval ticks died in the plots with no overhead shade, but some of those in the sheltered plots/.....

plots survived and eventually reached the larval stage. Perhaps in the more severe January drought all non-parasitic ticks were killed, even in the shady places. If this was the case, the relatively slow development of larvae in shaded places might explain why no clusters were found in such situations in February/March, although larval clusters were numerous in the warmer unshaded places. However, no larval clusters of B. decoloratus were found in the sheltered situations of the other farms which were surveyed later and were also warmer, and this makes one feel doubtful about the above explanation.

On the other hand, some of the autumnal data from the plot investigations and the surveys were apparently in agreement, since at Mount Pleasant, Grandon, Fort Willshire and the farm adjacent to Seaview, larval clusters were found in unshaded situations during the month of April or thereabouts.

R. evertsi and A. hebraeum.

The data for these two species are more scanty. However, some discrepancies are evident which are, in fact, similar to those in the case of B. decoloratus. Larval clusters of the two species were found in unshaded places in the autumnal survey at Trent, but could not develop successfully at similar times and in similar places at Mount Pleasant. Furthermore at Mount Pleasant the well-shaded situations appeared to be mainly favourable to the prelarval stages of both R. evertsi and A. hebraeum, but larval clusters were rare or absent in such situations in the surveys.

8. CONCLUSIONS.

- (i) In the main, the rate of development of pre-larval ticks was faster in the places which by day were warmer. However, at Mount Pleasant, development in Plot IV was sometimes slower, and never faster, than in the 'cooler' Plot V. Perhaps the most likely explanation for this is that extreme temperature fluctuations were responsible for delay in development.
- (ii) During hot, dry weather, conditions were sometimes sufficiently extreme to kill all the pre-larval ticks in the more exposed plots, while at least some of those in the well-sheltered plots survived and later reached the larval stage; this occurred most suddenly in a drought which followed on the cool months of winter and spring (1957);
- (iii) Considering the duration of the survival of pre-larval ticks failing to hatch successfully, it appears that in warm, dry weather, the stages in the most exposed plots died first, while those in the less exposed situations died later; it is not clear whether or not this was due to the cumulative effects of unfavourable conditions on the engorged female ticks and eggs. In view of the results of previous workers, there is some indication that abrasion of female ticks with soil may have hastened the death of ticks in the most exposed plot at Mount Pleasant.
- (iv) Very damp conditions such as exist after heavy rains may be able to kill some prelarval ticks;
the/.....

the eggs of R. evertsi appeared to be so affected in April/May 1958 in the most sheltered plot at Mount Pleasant.

- (v) Prolonged subjection to cool, damp conditions, may be unfavourable to the development or survival of prelarval ticks. In the case of B. decoloratus the most exposed plot at Mount Pleasant was favourable and the others were unfavourable in winter (1957) and a similar picture was obtained from the surveys.
- (vi) The plot data suggest that the prelarval stages of B. decoloratus, R. evertsi and A. hebraeum are more tolerant of hot-dry conditions than are the engorged females and eggs of I. pilosus, which agrees with the impression obtained from the surveys.
- (vii) Comparison of survey and plot results indicate that the absence of larval clusters of I. pilosus from unshaded situations in autumn at Seaview was because of the inability of the prelarval stages to survive the climatic conditions in such places.
- (viii) The plot data and the results of the autumnal surveys made at Grandon, Seaview, and Fort Willshire agree in showing that larval clusters of B. decoloratus, R. evertsi and A. hebraeum were to be found in unshaded situations in April or thereabouts. The data for February/March do not tally; at that time the larval clusters were found in unshaded places in the surveys at Trent but could not develop in such situations in the same months of the following year/.....

year at Mount Pleasant. Differences in the timing of dry periods in 1957 and 1958 may have been responsible for the apparent discrepancy. However it is also possible that, had larval longevity been investigated the plot data would have agreed with that obtained in the unshaded situations at Trent.

- (ix) The survey data for the well-shaded situations also disagrees with the picture obtained from the plot investigations. The larvae of B. decoloratus were able to develop in the sheltered plots in the first few months of 1958, and yet in the previous year no larval clusters of this species were found in such situations - even in a fairly well-infested area of Trent. Combination of a very severe drought in January 1957 and the slower development of larvae in the better-shaded situations may have been the reason for the apparent discrepancy. However this would hardly explain the apparent absence of the clusters from shaded places on the farms surveyed after Trent.

Observations on the behaviour of larvae and engorged female ticks have permitted the formulation of an alternative explanation for the absence of larval clusters in well-shaded places. These are considered in the next chapter.

MOUNT PLEASANT

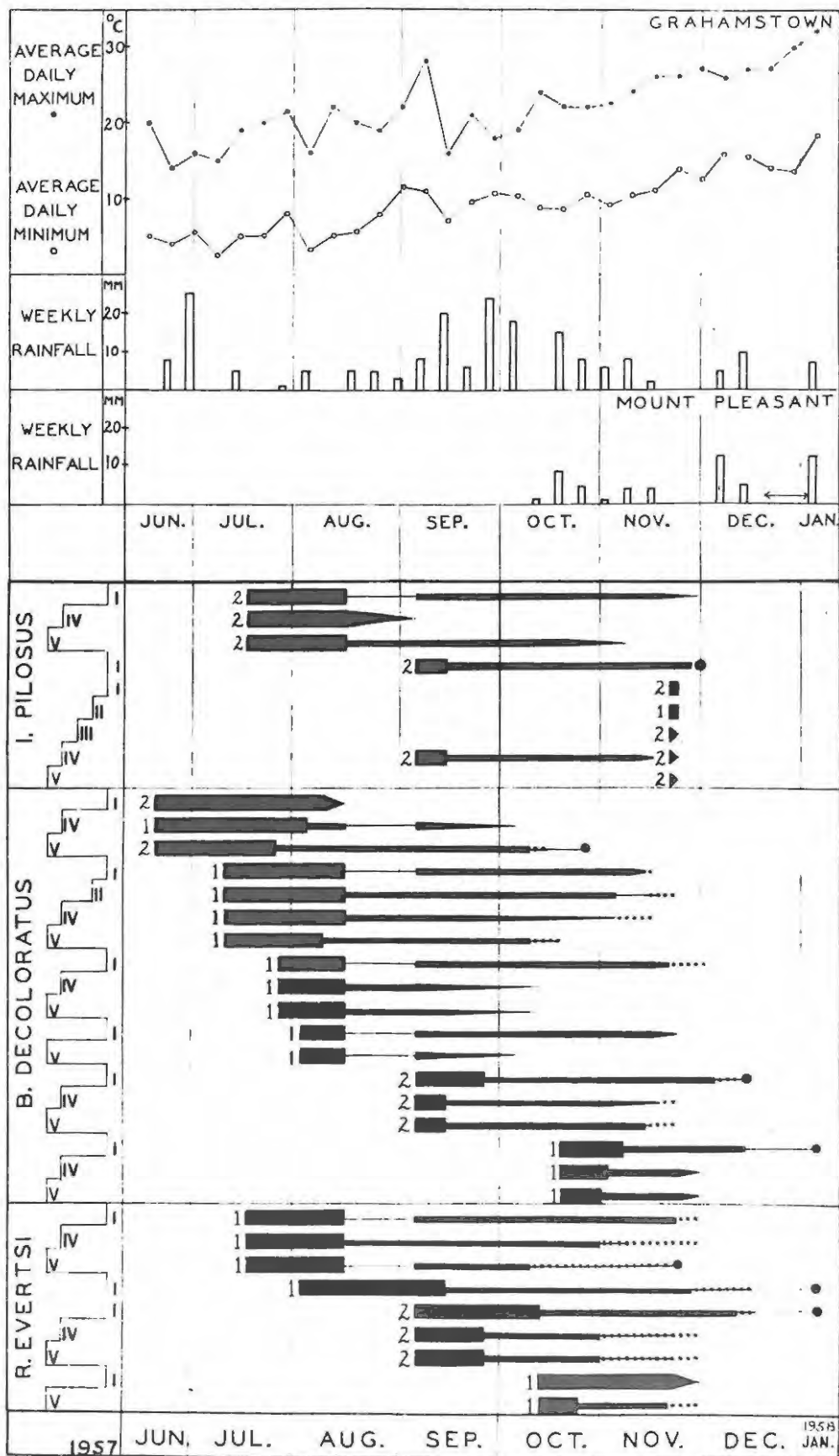
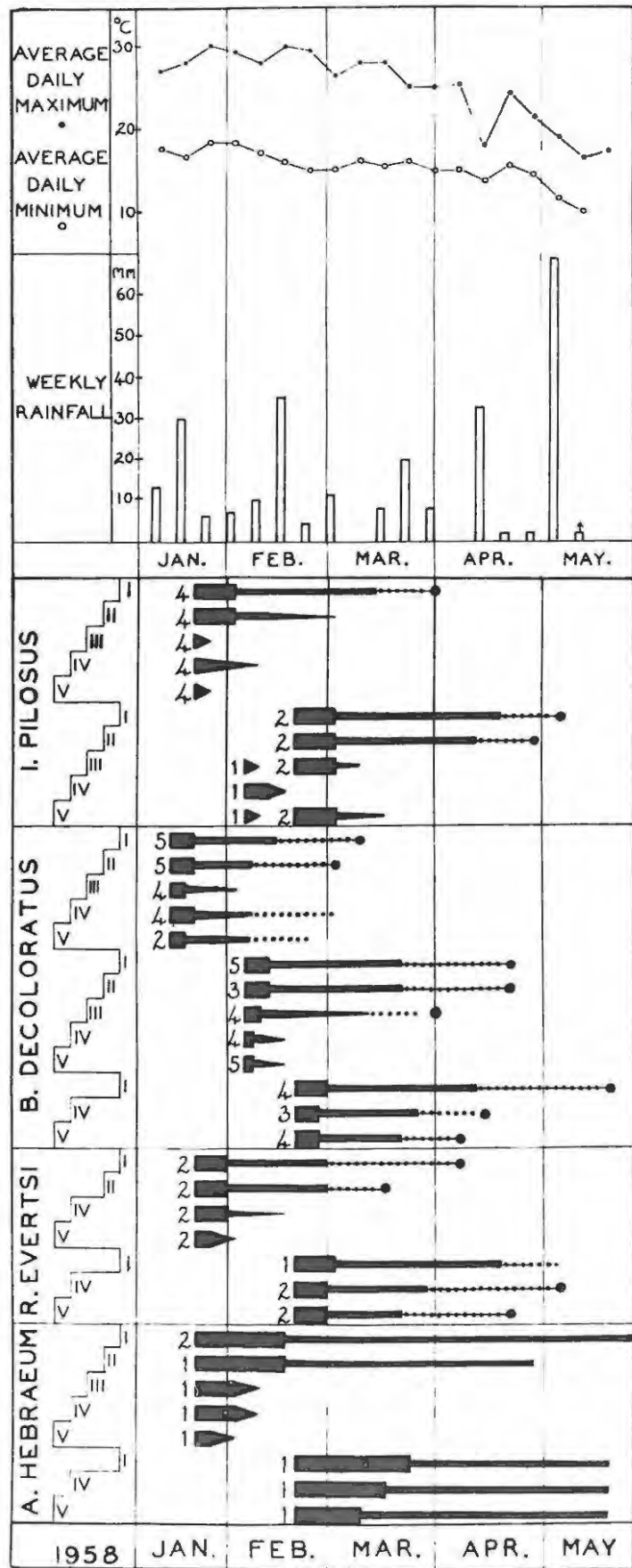


Fig. 2a



MOUNT PLEASANT

KEY TO SYMBOLS.

- = ENGORGED ♀♀ UNTIL SOME EGGS LAID.
- = UNSPECKLED EGGS.
- = SPECKLED EGGS.
- = LARVAE HATCHED.
- = TICKS OR EGGS DIED BETWEEN TIMES A & B.
- = 3 ♀♀ OF A BATCH.
- = SERIES OF PLOTS.
- = NO OBSERVATIONS.

Fig. 2b.

HOUNSLOW

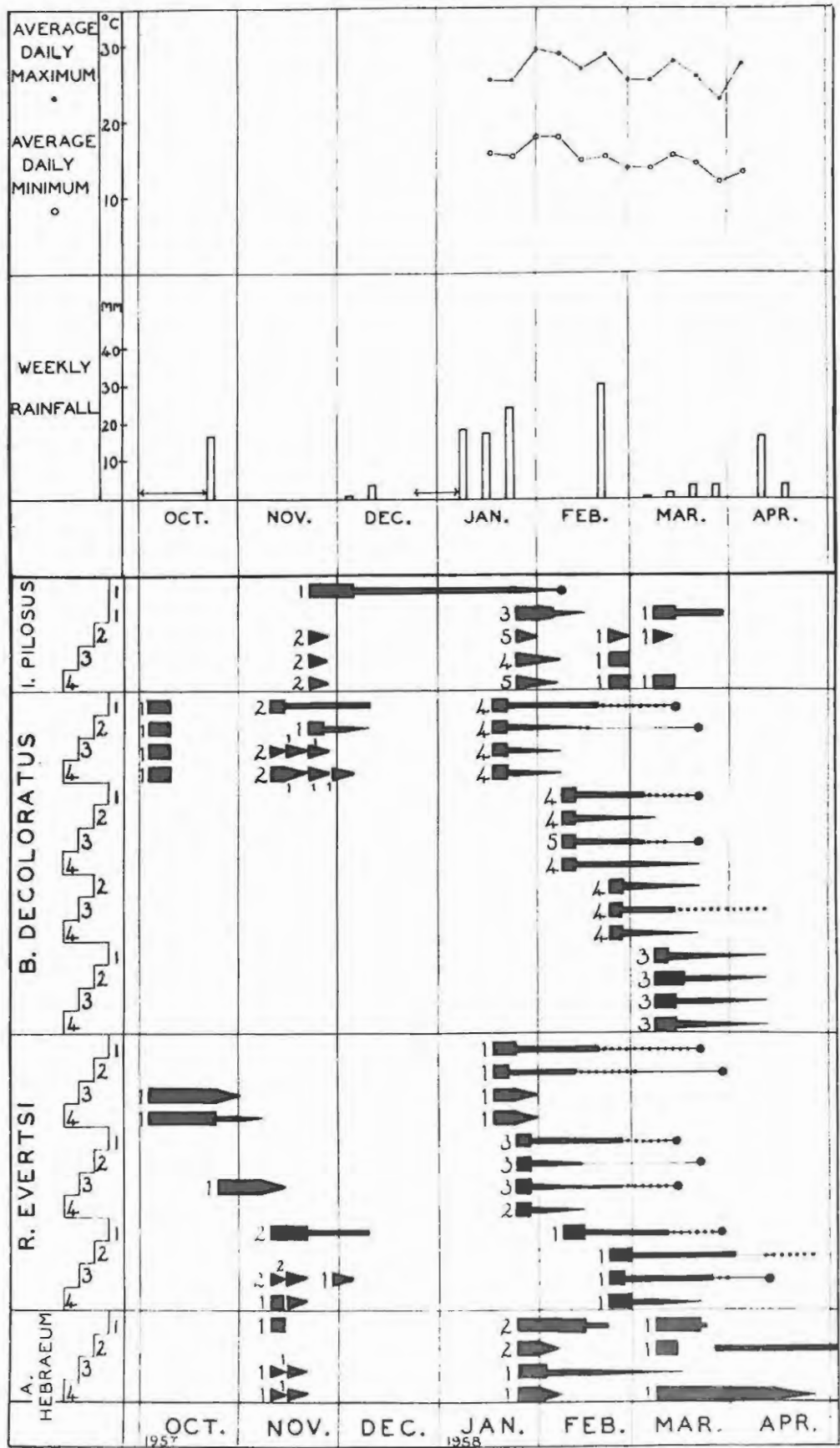


Fig. 3.

Photo 16 - MOUNT PLEASANT

This is a view from the south-west. The positions of the observation plots are marked. Plot 1 was on the right, in a part of the Euphorbia forest; Plot II/III was in the bushy area above the dipping-tank, visible on the left of the picture; Plot IV, indicated in the centre of the picture, was on the crest of the hillside; Plot V was west of the rows of trees near the farmhouse.



Photo 17 - HOUNSLOW.

This is a north-facing view of the Fish River Valley, and more particularly of the area of Hounslow in which observation plots were erected for the investigation of the survival and development of prelarval ticks. The position of Plot 1/2 is indicated by the X on the right of the picture; Plot 3 was on the slope towards the centre; and Plot 4 was in the open area shown on the left.



Photo 18.

Mount Pleasant - Plot I.

In this part of the plot in the Euphorbia Forest, the vegetation provided considerable shelter, although not quite Complete Overhead Cover. The survival and rate of development of prelarval stages of ticks in Plot I were investigated mainly in such a part of the plot. (cf the area shown in Photo 19 below).

Photo 19.

Mount Pleasant - Plot I.

This picture shows part of the same Plot I, but here there is no overhead cover and the lower vegetation grows very densely.

Photo 20.

Hounslow - The Gully in which Plot 1/2 was
Situated.

Photo 21.

Hounslow - Plot 1.

The low-lying part of Plot 1, under the large bush. At some times the vegetation was more luxuriant than in the case shown here.

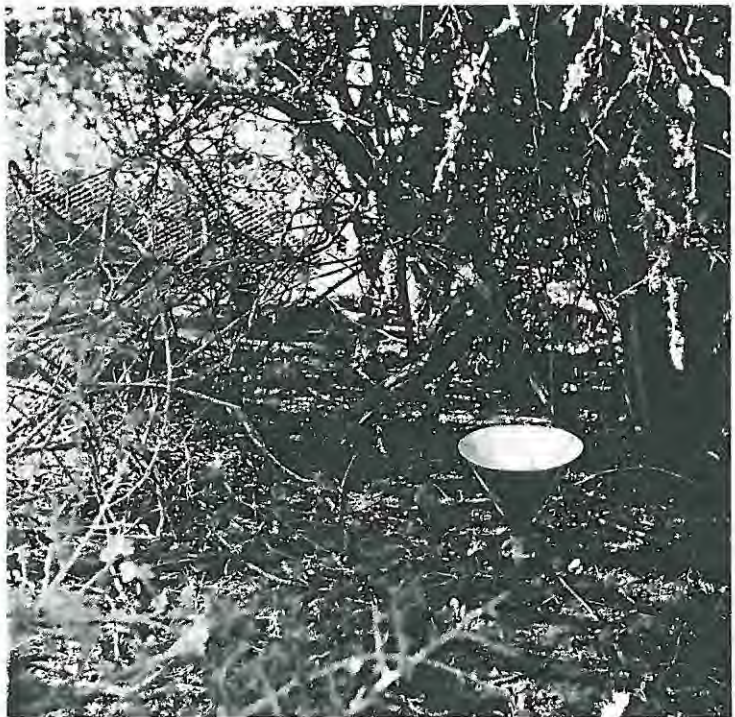




Photo 22.

Mount Pleasant - Plot II, part of a double plot.

The picture shows a situation in the shade of two large bushes which formed an archway over the south fence of the plot. Ticks placed under such large bushes or beneath the small bushes in the double plot were said to have been introduced into Plot II.

Photo 23.

Mount Pleasant - Plot III, part of a double plot.

The small bush shown in the picture was considered as part of Plot II, but the grassy unshaded part was Plot III territory. Note the slope of the ground.

Photo 24.

Hounslow - Plot 2.

Some of the dense thicket almost wholly surrounding this plot can be seen in the background, and the shadow of the large bush in the Plot 1 part is visible on the front edge of the picture.

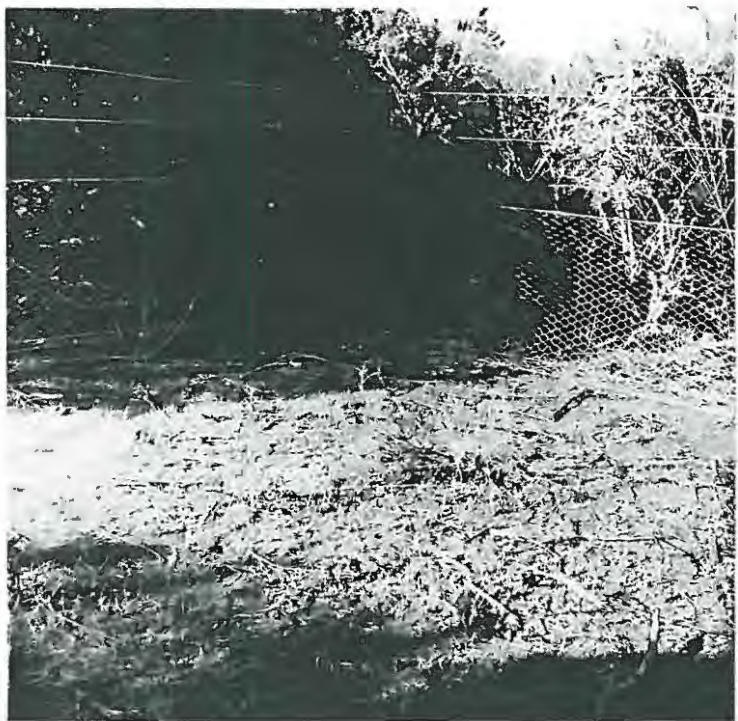




Photo 25.

Mount Pleasant - Plot IV.

The grass of this plot was at first short-cropped, but in the picture it is almost Medium-height. The automatic rain-gauge is shown here.

Photo 26.

Mount Pleasant - Plot V.

The proximity of the plot to a belt of trees to the east is illustrated in this picture. The vegetation in the plot is better seen in Photo 30.

Photo 27.

Hounslow - Plot 4.

At the time of the plot investigations, the area in the foreground of the picture was fenced, and the vegetation covering the soil was exceedingly sparse. The plot was considered comparable to the Plot V at Mount Pleasant. The photograph was taken, after the end of the investigation at Hounslow, when stoloniferous grass provided considerable ground cover.

Photo 28.

Hounslow - Plot 3.

The foreground area shown in the picture was fenced when the ticks were studied there. Although the ground-cover was scattered and much of the soil surface was bare, the clumps of grass and other low vegetation provided considerable shelter for ticks buried in these clumps. This plot was considered comparable to Plot IV, rather than Plot V of Mount Pleasant.





Photo 29.

A circular ward for confining engorged female ticks.

The circular wards had sides of 5 cm., which sloped from a wider top edge (34 cms.) to a narrower bottom edge (24 cms.) The inside surface of the walls was greased with Vaseline in an attempt to prevent the ticks from climbing over. The slope of the walls was such that they provided little shade and it was hoped that this would prevent the ticks from settling near or under the walls. The ward was fixed in position with large nails driven into the soil. The ward shown here was in Plot I at Mount Pleasant.

Photo 30.

Square wards and some partly-buried glass tubes.

The type of ward mainly used for confining female ticks was a square one, 23 cm. x 23 cm. The walls were verticle with angled top edges which effectively prevented the ticks from climbing over. The ward was fixed to the ground by means of pieces of wire as can be seen in the picture. These wards did not prove to be a satisfactory means of confining the ticks and thus most ticks were introduced into the plots in bottomless glass tubes, which are described in the text. The organdi caps of two groups of partly-buried tubes are visible in the picture, which was taken in Plot V at Mount Pleasant.

Photo 31.

Thermometer Screen, and Tube for thermometer
in the Soil.

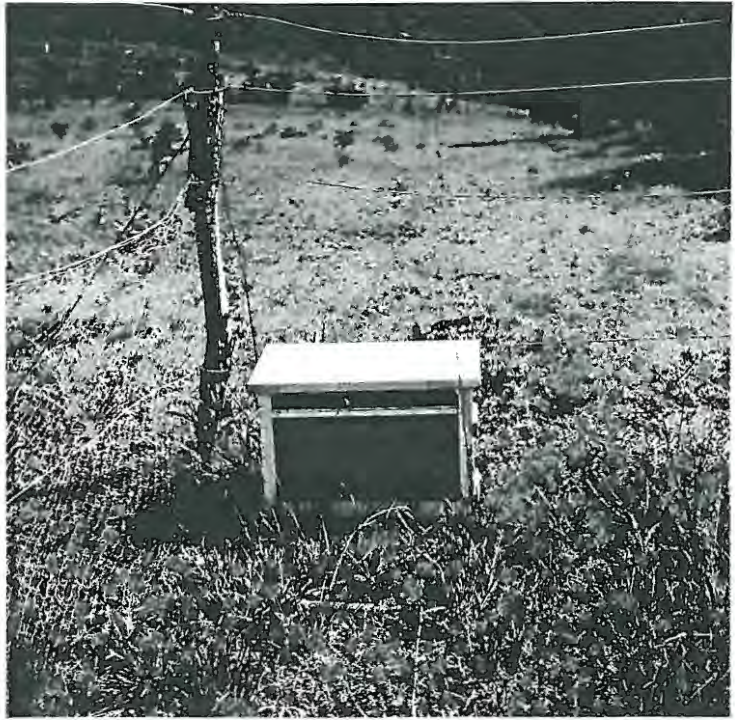
One of the thermometer screens is shown here. The slatted back and double roof are visible. The sides were closed but raised above the soil level. There was no floor and the thermometers rested horizontally on two cross bars so that the bulbs were about 5 cm. from the soil surface. The screen was faced south so that the thermometer was always in the shade.

A partly buried galvanized iron tube which contained a maximum thermometer can be seen in front of the screen. Normally the tube would be completely buried.

The picture was taken in Plot V at Mount Pleasant.

Photo 32.

A 'bottle-funnel' in Plot IV at Mount Pleasant.



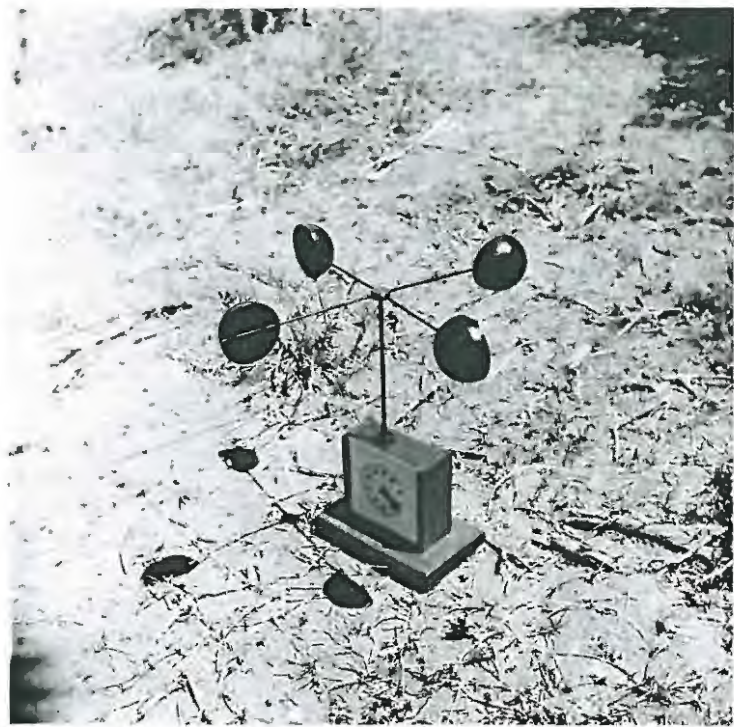


Photo 33.

A Piché Evaporimeter in Plot IV at Mount Pleasant.

Photo 34.

Cup anemometer in Plot 2 at Hounslow.

Photo 35.

Lengths of dowelling for observations on the vertical movements of unfed larval ticks.

The grass of the area enclosed by the shielding cage had, in this case, been clipped very short. Larvae were released at the bases of the lengths of dowelling and some settled at the tips of these. An attempt was made to establish that larvae of B. decoloratus do not migrate to the bases of their supports after settling at the tips, by painting the bases of the sticks with bird-lime, but unfortunately this substance soon lost its stickiness. The photograph was taken in Plot IV at Mount Pleasant in about October 1958.





Photo 36.

Shed at Fort Willshire where engorgement and falling of females of B. decoloratus from tethered hosts was observed. (Photograph taken in January 1959.)

Photo 37.

The cow at Mount Pleasant which was used for investigations of the falling of females of B. decoloratus. The photograph was taken in the morning, when well-engorged female ticks are usually numerous, as in the case shown here. The ticks are particularly abundant in the neck region.

Chapter IV - OBSERVATIONS ON THE BEHAVIOUR OF ENGORGED
FEMALES AND LARVAE OF B. DECOLORATUS.

1. INTRODUCTORY REMARKS.

The results of the surveys and the plot investigations suggest that the distribution of larval clusters of the four species considered can be partly determined by the effects of micro-climatic conditions on the survival or development of the eggs and the engorged female ticks. Indeed, in the case of I. pilosus such effects of microclimate seem to be the most important factors determining distributional limits within an infested area. On the other hand, both the surveys and the plot data relating to B. decoloratus suggest that other factors also have considerable effects. In the present chapter the behaviour of the larvae and engorged females of the latter species is considered, and it appears that some problems relating to the distribution of larval clusters of B. decoloratus may be explained on this basis.

The possibilities considered here are, that the distribution is affected by:- (a) the migrations of the larval ticks; (b) the wandering and settling down of the engorged female ticks; and/or (c) the falling of the female ticks from their hosts.

2. BEHAVIOUR OF LARVAL TICKS.

Theoretically the vertical migrations of the larval ticks might affect the distribution of larval clusters. For instance larvae might fail to migrate to the tops of the vegetation, or might leave the tops after

arriving/.....

arriving there. In either case the larvae could be missed in a tail-bar survey. However, although larvae of B. decoloratus were released into the five plots at Mount Pleasant on many occasions, there was no indication that vertical migrations of larvae had a significant effect. On the other hand, some observations indicated that horizontal movements of larval ticks may be important.

There are two ways in which the horizontal movements might affect the distribution of larval clusters:- (a) if the larvae move mainly in one direction, they might form a cluster some distance away from their hatching site, - perhaps in a type of situation where the development of the larvae could not have taken place; and (b), if, in certain types of situations, the larvae move in various directions and scatter, they might fail to form recognisable clusters.

(1) The Observations.

Some of the larvae observed in the field were reared in the laboratory at a constant temperature of 25-27°C and at about 70% R.H. Others were reared in the glass tubes buried in the surface soil of the plots where the larvae were subsequently released.

The usual course of events after hatching was similar to that described for I. ricinus (McLeod, 1932) and for R. evertsi (Gray, unpub.) For some days after hatching the larvae are in a state of relative inactivity, and are grouped close to the mass of egg-shells and unhatched eggs. During this period, the cuticles of the ticks are at first pale,

becoming/.....

becoming darker as they are tanned. Then the larvae become more active and migrate, eventually settling at the tips of the vegetation more or less immediately above the hatching site. There they settle in clusters, usually in the shade, e.g. on the undersides of leaves. (See also Lees & Milne, 1951; and Wilkinson, 1953). Here the larvae 'wait for a host'. There were no indications of considerable migration of larvae away from the vegetation tips after settling (cf Wilkinson, loc.cit; Snowball, 1957).

It was noticed that in some circumstances the larvae formed clusters several centimetres horizontally away from the spot where they were released. (a) At a time when the grass of Plot IV was green and no longer short-cropped, the grass in part of that plot was clipped close to the soil level. A mass of laboratory-reared larvae was released in the centre of the clipped area. Some days later the larvae were found, about 25 cms away, on the tips of the 8 cm-high grass at the edge of the unclipped area. (b) In Plot II/III several tubes of field-reared larvae were placed among the lower branches of a small bush in that plot. The bush was about one metre high and equally wide, and the soil beneath it was completely shaded for most of the day. The caps of the tubes had been removed so that the larvae could wander out onto the branches and leaves. A week later some of the larvae were found at the ends of the low branches on which the tubes rested, and a few were on contiguous foliage. All these larvae had apparently walked upwards before settling down. Of greater interest in the present context was
the/.....

the presence of larvae on grass which grew beside the bush. It is possible that these larvae ^{had} migrated downwards to the soil level, and ^{had} then walked horizontally for about 50 cms, before climbing to the tips of the grass. There is, however, the possibility that these larvae had fallen from the tick-laden branches, which were almost immediately above them.

(ii) Possible Causes of Horizontal Migrations.

Before one can make any deductions about the effects of larval migrations on the distribution of the clusters, it is desirable to know something about the factors affecting such migrations. Several workers have investigated the orientating mechanisms of larval ticks (see Dethier, 1957), but so far the results for different species, and even for the same species, do not form a very coherent picture.

Contradictions are less in the case of the genus Boophilus than in Ixodes. This is perhaps because the former has been less investigated than the latter, but it may be because the migrations of boophilids are the simpler. The unfed stages of Ixodes have been shown to migrate downwards as well as upwards (Lees & Milne, 1951), whereas the larvae of Boophilus species possibly remain at the vegetation tops once they have initially settled there (see above).

Krijgsman (1937) has studied the larvae of Boophilus annulatus (Say) in the laboratory, and his results are of interest in the present context. He found no gravity response, and although the larvae

were/.....

are attracted to high temperature and high humidity under some circumstances, Krijgsman considers that light is the important factor which attracts the larvae to the vegetation tips. Immediately after hatching the larvae of B. annulatus avoid light, but, as days pass they move to lighter regions and eventually are attracted to bright light. The same result is obtained regardless of whether the larvae are kept in the light or in total darkness from the time of hatching to the time of the experiment.

Similar changes in light response of the larvae of B. decoloratus could mainly explain why at first these ticks remain at the bases of the vegetation, and later migrate to the vegetation tips. A light response could also explain the horizontal migrations. On very short-clipped grass in part of Plot IV the larvae scattered away from their point of release until they came to the unclipped grass where they climbed upwards, possibly because there the light came mainly from above. The possible downward and then horizontal movement of larvae from the lower branches of a bush in Plot II/III could have been because the 'body' of the bush appeared darker than the soil beneath and thus some of the larvae were attracted to soil level by light, and from thence to the unshaded grass beyond the bush, also by light.

iii) Possible Effects of Horizontal Migrations on the Distribution of Larval Clusters.

The field observations have provided some evidence to show that the larvae of B. decoloratus migrate horizontally/.....

horizontally in some circumstances, but is it likely that the picture of larval cluster distribution can be considerably affected by horizontal migrations? The observations on survival and behaviour at Mount Pleasant, and Krijgsman's (1937) laboratory investigations on B. annulatus, suggest that the following hypothetical events may be possible:-

(a) It is a place where there are scattered bushes and in between the bushes the vegetation is sparse. The climatic conditions have been hot and dry, and, as a result, all prelarval and larval ticks beyond the shelter of bushes have died. Some prelarval ticks under the bushes survived the drought, and when the larvae hatched the drought was already broken. Their cuticles tanned, the larvae wander towards the light and away from the shade of the bushes. Some wander mainly in one direction since light comes more strongly from one side; these settle in recognizable clusters on the tips of sparse vegetation nearby, - in a type of place where the prelarval stages could not have survived.

(b) It is an area where there are scattered tree clumps. The trees provide complete overhead shade but considerable light shows at the edges of the clumps. There is little substorey vegetation, the soil being covered mainly with leaf debris. Some engorged female ticks have laid eggs near the centre of the clump, where the debris is trampled rather flat. The larvae hatch, and when their cuticles are tanned they are attracted to the light which is visible mainly laterally. They walk horizontally over the
flattened/.....

flattened debris, and consequently scatter and do not form recognizable clusters.

The second state of affairs described above could apply to Bush Camp at Trent in autumn. Indeed it appears possible that horizontal scattering of larvae has some bearing on the apparent absence of larval clusters of B. decoloratus from well-shaded situations.

Another, relatively minor point is worthy of some mention. In Chapter II it was stated that no larval clusters of B. decoloratus were found on the bushes of the infested part of Gum Trees Camp at Trent in autumn. It would seem probable that larvae hatching under the bushes migrated horizontally towards the sun-lit grass beside the bushes. But it should be noted that in this case larvae doubtless hatched also in the grassy parts, and thus this is not an example of movement of larvae from a favourable place to one where larvae could not have developed.

3. WANDERING AND SETTLING-DOWN OF ENGORGED FEMALE TICKS.

The behaviour of engorged female ticks after they have dropped from their hosts may affect the distribution of the larval clusters in two ways:-

(a) if the females avoid certain field situations, larval clusters will not be found in such places (unless the larvae migrate there); and (b) if the female ticks in some situations frequently move about after the onset of oviposition, eggs might be laid in small groups, and thus large compact clusters of larvae would not form in such places.

Some preliminary observations have been made which

provide/.....

provide indications relating to these possible effects.

(i) Methods.

More or less continuous observations were made to provide information about the settling of engorged females of B. decoloratus. The behaviour of the ticks was first noted in March 1958, in a low-lying part of Grahamstown. The engorged females had been collected on the morning of 26th March and kept in a glass tube stoppered with dry cotton-wool, until they were introduced into the field in the afternoon of the same day. At about 2.45 p.m., five female ticks were dropped into three different types of situation. Two ticks (A and B) were dropped on the surface of a damp mat of rotting leaves, which was partly sheltered above and to the east by a small tree and a creeper-covered fence. One tick (C) was introduced into a place where there was grass, 5-10 cms high, which was dense in patches, and where the areas between the grassy patches were covered with grass debris. Two ticks (D and E) were dropped where there was much bare ground and here and there patches of straggling weeds and sparse grass. During the afternoon of 26th March, the ticks were observed with the aid of students so that they could be studied simultaneously. On subsequent days their movements were noted intermittently by a single observer.

A second series of observations was made in July 1958 in a higher area, henceforth referred to as the 'Grahamstown plot'. Here there was less ground cover than in the most exposed situation in the low-lying area. Ticks had been collected on the morning of 30th June and kept in a glass tube, with dry cotton-wool stopper,

until/.....

until they were dropped in the plot on the following day. Five ticks were dropped at different times of the day. Two (P and Q) were introduced into the plot at about 10.00 a.m., another pair (R and S) at about 2.00 p.m. and one (T) at 5.00 p.m. on 1st July.

In both series of observations the engorged females were permitted to wander freely while they were being continuously observed, but when left unattended, those in the Grahamstown plot were surrounded by a circular ward (Photo 29). Despite this attempt to confine the ticks, some were lost between visits to field situations.

(ii) Results.

The aspects of the wandering and settling of engorged female ticks which may have some effects on the distribution of larval clusters are considered below.

(a) Righting.

Engorged female ticks dropped from a height of about one metre sometimes come to rest on their ventral surfaces, but frequently, after falling, they lie on their dorsa. This happens even when the ticks are dropped on a smooth and level floor. Righting is achieved by contractions of the opisthosoma, causing rocking and rolling, and movements of the legs which bring the claws of one or more into contact with the substratum. If the claws grip the surface the tick is usually able to drag its body over by flexure of a 'fixed' leg. It was found that the ticks were unable to turn over if they lay on dry sand, or finely-divided plant debris, since they could not grip such substrata.

(b) Walking.

The ticks observed walked as long as they were in
sunlight/.....

sunlight. They also walked in shade, but sometimes settled there (see below). In the low-lying place, one tick (D) walked for an hour in sunlight over bare ground, when the temperature on an exposed thermometer was 34°C. During this period the tick walked about 75 cms. and travelled a straight distance of about 34 cms. Some of the ticks observed in the Grahamstown plot must have covered greater distances while exposed to direct sunlight, but these were not measured. During the July observations the temperature of the soil did not rise above 28.5°C.

(c) Orientation.

Ticks walking in sunlight appeared to orient towards vegetation a few centimetres away, usually towards shady sides. Also there was sometimes a tendency for ticks to walk in a certain direction, perhaps towards a tree a few metres away (See Appendix)

After wandering in the shelter of sparse vegetation, or under debris, ticks emerging into the sunlight on bare ground would sometimes turn about and return to the shelter from which they had just come.

(d) Temporary Settling. (Table 14).

During the July observations it was noticed that the engorged females were inclined to seek shelter in the mid-period of the day. Ticks creeping under small patches of debris or vegetation at this time tended to remain under cover until later in the afternoon, or the following morning. This type of settling may have been due to avoidance of bare ground during climatically extreme times of the day (see above).

Both the March and the July observations suggest

that/.....

Table 14- Summary of observations of the wandering and settling of engorged female ticks (P-T) in the Grahamstown plot. (W= wandering; BA= burrowing attempts; S₃=^{third time a certain} tick seen to have settled)

Date Time of day.	Time of introduction					Climatic conditions		
	10.00 a.m.		2.00 p.m.		5.00	°C	RH	Light
	P	Q	R	S	T			
July 1								
10.- 11.00 a.m.	W	W				17°		
- 12.00	BA	BA				23°		
- 1.00 p.m.	S ₁	BA						
- 2.00	S ₂	-				28°	16	
- 3.00	W	W	W	BA		25°		
- 4.00	BA	W	W	BA		22°		13
- 5.00	S ₃	W	W	W		16°		10
- 6.00	S ₃	S ₁	S ₁	W	W			
July 2								
10 - 11.00 a.m.	S ₃	S ₁	W	S ₁	S ₁	18- 21°	49- 37%	15- 14
- 12.00	W	S ₂	S ₂	S ₁	S ₂	25°	36%	15
- 1.00 p.m.	S ₄	S ₃	W	-	S ₃	26°	20%	15
- 2.00	S ₄	S ₃	-	-	W	25°		16
- 3.00	S ₄	S ₃	S ₃	S ₂	-	25°		16
July 3								
10 - 11.00 a.m.	S ₄	S ₃	S ₃	S ₂	S ₄	19°	41%	16
- 12.00	-	-	-	-	-	-	-	-
- 1.00 p.m.	-	-	-	-	-	-	-	-
- 2.00	S ₄	S ₄	S ₄	S ₂	W	24°		16
- 3.00	-	-	-	-	-	-	-	-
- 4.00	-	-	-	-	-	-	-	-
- 5.00	S ₄	S ₄	S ₅	S ₂	S ₅	19°	41%	13
July 4								
10 - 11.00 a.m.	S ₄	S ₄	S ₅	S ₂	S ₅	15°	80%	14
- 12.00	S ₄	W	S ₆	S ₂	S ₆	21°	64%	16
- 1.00 p.m.	-	-	-	-	-	-	-	-
- 2.00	S ₄	W	X	S ₂	X			
- 3.00	S ₄	S ₅				19°	55%	13

(Temperature recorded in loose soil; Relative Humidity recorded about 30 cms above the soil surface; Ikophot light meter used to record light reflected from a horizontal white surface.)

that there was little or no wandering at night. For instance, in the mid-afternoon of 1st July, all four ticks which by that time had been introduced into the Grahamstown plot were actively wandering, but, from 4.00 p.m. onwards their movements became slower, and by 5.00 p.m. two of the four (P and R) had partly buried themselves and were immobile. Of the remaining two ticks one (Q) was immobile although completely exposed, and the other (S) was walking very slowly. A fifth tick (T), introduced at 5.00 p.m., also moved slowly at this time. On subsequent days all five ticks were stationary during the night, but these had mostly settled early in the afternoon. Several ticks became active in the mornings, after being immobile at night.

(e) More Permanent Settling-down (Table 14).

In the Grahamstown plot two ticks which settled during the midday period of 2nd July, remained in these settling places apparently permanently. One (P) had been introduced in the morning of 1st July. At about noon of the following day this tick buried itself in loose soil under the edge of a metal ward. The other tick (S) had been dropped into the plot at 2.00 p.m. of 1st July. It settled 'permanently' under a rock at about the same time as the above-mentioned tick (P).

Four of the five ticks dropped in the low-lying place settled for long periods (of more than 18 hours). The fifth tick (E) was temporarily lost and was perhaps settled during that time. Two ticks (A and B), in the most sheltered situation, disappeared into the mat of debris within a few minutes of being dropped. They settled not more than 4 cms. away from their initial

positions./.....

positions. The tick (C), in the grassy place, fell on grass debris and for about 40 minutes it wandered and attempted to burrow before it managed to penetrate some debris at the base of rooted grass. Its settling place was only 4 cms away from the spot where it was dropped. The one tick (D) which eventually settled in the most exposed of the three situations, showed no signs of burrowing or settling for at least two hours after it was introduced, and it eventually settled in a superficial position in the shade of weeds, a spot about 45 cms. from its original position.

(f) Wandering After Settling-down.

Four days after two ticks (P and S) had settled 'permanently' in the Grahamstown plot, one under a rock and the other in soil at the edge of a ward, the pair were still in the same positions. On the other hand all the ticks in the low-lying place disappeared from the spots in which they had settled, within two days of their settling. This was probably not comparable with migration of ticks after temporary settling during the night or over the climatically most extreme time of the day as seen in the Grahamstown plot. In the low-lying place all the ticks had settled for more than 18 hours before they disappeared from their settling-places.

Since the ticks could not be found elsewhere, it is possible that they were removed by predators. However, predation is an improbable explanation because females of other species of ticks were also introduced into the three types of situation on the afternoon of 26th March and these disappeared at different times to those of

B. decoloratus/.....

B. decoloratus. One would expect predators to remove all ticks from a situation, and not first those of one species and then those of another.

The engorged females of B. decoloratus in the sheltered situation moved first, and the one which settled in the most exposed area was the last to go (see Table 15).

Table 15 - Summary of observations on the behaviour of female ticks (A-E) in the low-lying place.

Date	Time of Observation	Description of Situation					Weather
		Under Tree		Grassy	Sparse Vegetation		
		A	B	C	D	E	
March							Heavy rain during the night before.
26	5.00 p.m.	S	S	S	BA	W	Fine.
27	9.30 a.m.	S	S	S	S	X	Fine.
	2.30 p.m.	X	X	S	S	X	Fine.
	5.00 p.m.			X	S	W	Fine.
28	9.30 a.m.				S	W	Fine.
29	11.30 a.m.				X	X	Night of drizzling rain.

Symbols: W - walking; BA - burrowing attempts;
S - settled; X - lost.

(g) Wandering After the Onset of Oviposition.

Oviposition was not recorded in the Grahamstown situations, but it was noted on several occasions in wards at Mount Pleasant. There was slight evidence of wandering of engorged females of B. decoloratus after the start of egg-laying.

In/.....

In June 1958, female ticks were placed in wards of Plots I, IV and V at Mount Pleasant. The ticks in Plots I and IV disappeared after laying a few eggs whereas the tick in Plot V remained permanently in its initial oviposition site. The disappearance of ticks may have been due to predation, but it is possible that they walked away from their first oviposition sites.

At an earlier stage, in February 1958, two engorged females were placed in a ward of Plot III. After several days, the ticks were found dead in exposed positions in the centre of the area enclosed by the ward. A few eggs adhered to the anterior parts of the bodies, in a scattered fashion, which suggested that these eggs represented only some of those laid. It is probable that the two ticks had laid eggs elsewhere in the confines of the ward, and had then moved away from their oviposition sites with a few eggs still clinging to them.

(iii) Possible Factors Affecting Wandering and Settling.

The autumn and spring surveys yielded many compact larval clusters of B. decoloratus, and observations of ticks in wards at Mount Pleasant showed that the engorged females often, if not usually, laid hundreds or thousands of eggs in a mass. The central question of the present section is: do the engorged female ticks choose oviposition sites, or will they settle and lay a mass of eggs anywhere? Although oviposition was not observed in the Grahamstown situations, some relevant indications were obtained and these are discussed below.

To choose a settling-place after falling from its host, it is necessary that a tick be able to move about.

The/.....

The observations show that if an engorged female falls on its dorsum, it may be unable to right itself because of the nature of the substratum. When this is the case, ticks must remain where they drop. It is possible that ticks are sometimes unable to wander because temperatures are too low for activity; in these cases the females are perhaps also unable to lay eggs. The inactivity of ticks at night during the Grahamstown observations was perhaps because of low temperature, but it is also possible that low light intensity was an important factor in this instance.

The observations suggest that choice of settling-places may be aided by orienting mechanisms. Of particular interest are the indications that engorged female ticks oriented towards a tree a few metres away. These were noted in the afternoon, the tree being to the west of the two ticks apparently attracted to it (see Appendix). On ground with few obstructions, and under favourable climatic conditions, engorged females of B. decoloratus can probably cover three metres in as many hours. Thus, orientation towards vegetation some metres away may have a significant effect on the distribution of ticks in some circumstances. The observations also suggest that the ticks may be able to orient towards the shady sides of grass tufts only a few centimetres away. This might be important, if, for instance, the tufts are so widely separated that the ticks seldom come upon them by chance, and conditions are less favourable in the bare areas between the tufts (see below). Lees (1948) has found that engorged nymphs of I. ricinus when presented with a wall of vertical black and white stripes, will orient towards the dark stripes. Perhaps a similar skototactic response leads engorged

females/.....

females of B. decoloratus to trees or to nearby tufts of grass. On the other hand, temperature and/or humidity gradients could have similar effects.

All the engorged females of B. decoloratus released in the wards at Mount Pleasant buried themselves partly or completely before laying eggs. Whether the biological significance of this relates to climate or to predation, burrowing appears to be an important part of the settling-down behaviour.

In the Grahamstown situations burrowing attempts were frequently observed. It seemed that ticks would not try to burrow while exposed to direct sunlight, and thus perhaps this behaviour is linked with low light intensity. Apparently ticks only sometimes attempted to burrow when they moved into shade, but this may be an illusion due to the short duration of some burrowing attempts and the interrupted nature of the observations. In other words, ticks seen to be wandering in the shade without trying to penetrate the substratum, may have in fact attempted to burrow seconds before, while the observer was watching another tick. In any event, it is possible that environmental factors other than light play a part in determining whether or not engorged females will try to burrow.

Success of burrowing appeared to be largely determined by the penetrability of the substratum, as one would expect. In March the two ticks on the deep mat of debris burrowed in almost immediately; the tick in the grassy place soon tried to burrow but only managed to penetrate grass debris 40 minutes after being dropped; the two ticks in the place with sparse vegetational

cover, /.....

cover, and mainly impenetrable substratum, apparently failed to burrow successfully although they made several attempts. In July burrowing attempts were made during the first day of the observations, but it was only on the second day that two ticks buried themselves, - in circumstances which they had not previously encountered. One tick crept under a rock, and the other burrowed into loose soil under the edge of a metal ward.

The suitability of the two latter-mentioned situations suggests that a rigid object may aid burrowing, or may provide thigmotactic stimuli which are conducive to settling. In this connection it is worth recalling the frequently-observed tendency for ticks to settle against the walls of the square wards at Mount Pleasant. There it was also noticed that stones, and tufts of stiff grass on occasion served as settling-places, whereas the female ticks were apparently disinclined to settle in softer, untufted grass, or in loose debris.

All ticks in the Grahamstown situations which were seen to have buried themselves wholly or almost completely, subsequently remained in their buried positions for at least 18 hours, some for several days, and the two which burrowed in the Grahamstown plot possibly permanently. On the other hand, one tick settled for several days while remaining in a superficial although shaded position. This tick was one of the pair dropped in the low-lying area in March, and comparison of the wanderings of the ^{two} ticks provides a possible explanation for the apparently exceptional type of settling.

Tick/.....

Tick E seemed to confine its wanderings of several successive days to the sparse vegetational cover and possibly did not settle except at night. This tick was probably unable to penetrate the substratum. Tick D was dropped on bare ground and walked in direct sunlight for an hour before it came upon a patch of sparse cover where it wandered more slowly. But although the latter tick was apparently unable to penetrate the substratum, it did not continue wandering on the second and subsequent days of the observations, but settled superficially with its capitulum under a stalk of vegetation. Perhaps this tick was in some way exhausted by its long exposure to direct sunlight.

If wandering in direct sunlight can impair the subsequent movements of the engorged female ticks, as the above would suggest, the 'temporary settling' of ticks which was observed in the July observations during the midday periods would seem to be of significance. These ticks did not burrow but merely crept under loose debris or vegetation lying on the soil. In a previous section it was suggested that ticks settling during the mid-period of the day were seeking shelter and avoiding the bare ground during climatically extreme times of the day. This was indicated by the fact that some of these ticks wandered away from their settling-places when climatic conditions were evidently less extreme.

Some of the ticks settling for more than 18 hours disappeared from their settling-places. It seems likely that they walked elsewhere and were not removed by predators. Assuming that they did walk away, it is of interest to consider possible factors causing this.

It/.....

It was in the low-lying area in Grahamstown that disappearances of ticks from 'more permanent' settling-places were noted. The fact that the ticks in the most damp situation were the first to be lost suggests that prolonged subjection to moist conditions may have disturbed the ticks. Although engorged ticks are probably unable to take up water from moist air, as can unfed stages, (Lees, 1946; Hitchcock, 1955b) perhaps they are affected by exposure to free water. Another possible explanation for disturbance of the ticks in the low-lying situation is that the shifting of the covering debris during occasional observations caused the ticks to move. In fact the ticks disappearing first were those which were most deeply buried, and thus examination of them may have involved the most disturbance.

Wandering after the onset of oviposition seems to be unusual, but perhaps it is not more so than earlier wandering after settling in an initially favourable place. (Lees (1948) states that engorged females of I. ricinus do not wander after the start of egg-laying but provides no supporting data.) It has been suggested above that very wet conditions may have disturbed ticks which had not yet laid eggs. At Mount Pleasant ticks which had laid a few eggs disappeared from cool moist places while one remained in a place where evaporation was relatively high. Thus, in this case, moisture once again would seem to be a possible disturbing factor. On another occasion a pair of ticks in an exposed situation at Mount Pleasant was probably forced to move from their oviposition sites because of high temperature.

(iv) Possible Effects of Wandering and Settling on the Distribution of Larval Clusters.

In the autumn and spring surveys larval clusters of B. decoloratus were found over a wide range of situations. They were however uncommon in areas with sparse vegetational cover, and were apparently absent from areas with complete overhead shade. The observations on the behaviour of the engorged female ticks show that the rarity of larval clusters in certain types of field situations is possibly, although not probably, because of frequent movements of ticks during their oviposition periods. For example there are slight indications that ticks in exposed situations may move about because high temperatures are not conducive to permanent settling, while those in the well-sheltered places may be disturbed by prolonged exposure to free water. On the other hand, the wandering and settling behaviour of ticks before each deposits its eggs in a single mass, may account for the rarity of larval clusters in certain situations, provided ticks do not have to cover straight-line distances of more than say six metres to avoid these places. In the following paragraphs the expected behaviour of engorged females in four types of circumstances are described to illustrate possible effects of wandering and settling. These accounts must be considered as very tentative until the factors apparently involved have been critically studied.

(a) Exposed situation such as Plot 3 at Hounslow.

(Photo 28).

It is probable that not all engorged female ticks

would/.....

would be able to avoid the more exposed places in such an area, even if they fell within six metres of bushes. Firstly, some ticks might fall on their dorsa, on ground covered with finely-divided sheep faeces and so be unable to right themselves. Secondly, ticks would probably settle at least temporarily in grass tufts and stones, for instance during the mid-periods of the day, and this would reduce the time available for wandering before the onset of oviposition. Thirdly, those ticks falling more than about three metres away from bushes might be too far away to orient towards them, in which case their chances of reaching a bush would be slight.

- (b) Exposed situation such as a Fort Willshire area with sparse and dry stoloniferous grass not far from bushes (Photo 15).

Ticks falling within six metres of a bush in such a situation might reach it if the exposed area in which the ticks fell had the following attributes: the soil surface were favourable for righting; the surface were too firm and the soil cover too sparse to encourage settling; the soil cover were sparse enough to permit ticks to walk easily and to orient towards a bush; and the bush were such that ticks could orient towards it from a distance of six metres. On the other hand some ticks, being exposed to sunlight during the mid-period of the day might subsequently be too 'exhausted' to reach the shelter of a bush.

- (c) Exposed situation such as parts of the fallow land in Bananas Camp at Trent (see II. 5. i.)

If ticks were dropped in such a place about six metres/.....

metres away from a patch of grass, it is unlikely that they would reach it, mainly because they would be unable to orient towards the grass, but also because of obstructions to movement. Also the dappled shade provided by dry stalks of weeds might encourage the ticks to settle at least temporarily in various types of niches closer to the places where they fall.

(d) Well-sheltered situation such as in the tree clumps of Bush Camp at Trent.

All the ticks falling in tree clumps would probably settle there at first but might eventually leave such places. This might happen if conditions were damp enough to render it unsuitable for long-term settling, temperatures were sufficiently high to permit activity and debris did not present too much obstruction to the progress of wandering ticks.

The above would suggest that the wandering and settling of engorged females of B. decoloratus may affect the abundance of larval clusters in certain types of field situations (for instance b and d above). Whether the effect is great or small must depend largely on the actual distances which the ticks can travel under various circumstances. This aspect might be fruitfully studied after the factors involved have been critically investigated.

4. THE FALLING OF ENGORGED FEMALE TICKS FROM THEIR HOSTS.

It is of interest to find out whether or not females of B. decoloratus generally fall in certain types of field situations although their hosts cover a wider range. For instance this might be the case if

the/.....

the ticks release their grip on the hosts only under certain microclimatic conditions. During the course of the observations yet another possibility became apparent, namely that the engorged females fall in certain places and seldom in others because of a combination of a more or less fixed pattern of 'tick-fall', and a pattern of ranging behaviour by the hosts.

Previous workers have already obtained a certain amount of information relating to the falling of engorged female ticks. It has been noted that the final stage of engorgement takes place usually during the night (Stampa, 1959; Kneisen & Lavrenko, 1956). The diurnal rhythm of engorgement and falling in Ixodes persulcatus (Schulze) has been investigated by Balashov (1954). He induced host cattle to be active sometimes mainly by day and sometimes by night, and came to the conclusion that final engorgement takes place while the host is at rest, whether this be by night or by day. The above-mentioned workers and also Hitchcock (1955a) have found that most engorged females fall in the early part of the daytime. Balashov (loc. cit) relates peak tick fall to host activity after a period of rest, irrespective of the time of day (see also MacLeod, 1932).

In the following sections some preliminary observations of the falling of females of B. decoloratus under various circumstances are described and possible effects of this on the distribution of larval clusters are discussed.

(i) Pattern of Engorgement and Dropping of Female Ticks.

Some observations were made to find out if there is a pattern in the tick-fall of B. decoloratus, and whether or not this is correlated with numbers recently attaining complete engorgement, as the results of previous workers suggest. At Fort Willshire in May 1957, an opportunity arose for the investigation.

Two Afrikander bullocks had been tethered in a shed to tame them, and they happened to be fairly well-infested with B. decoloratus. The beasts had already been tied up for about two weeks, and had not been dipped for three weeks, when the observations were commenced. The shed housing the two animals is shown in Photo 36. It was three-sided, being open on the north-east side. During the investigation the bullocks were in the shade except in the early morning when their hind-quarters were in sunlight if the eastern sky was clear. Feeding and watering of the bullocks took place three or four times a day, at approximately the following times:— 7.30 a.m.; 10.30 a.m.; 12.30 p.m.; and 4.30 p.m.

Methods.

Since the bullocks were not very heavily-infested with ticks, the following method of investigation was practicable. Sketches were made of the sides and hind view of each animal and the ticks which appeared to be well-engorged (more than 130 mg. in weight) were shown on the drawings. Periodically the beasts were examined from a distance of about 1.5 m. and the distribution of their well-engorged ticks was compared with the picture provided by the sketches. There was no

indication/.....

indication that the female ticks changed their places of attachment (see also Arthur, 1960 p.213). Thus a tick disappearing from its recorded position was noted as having dropped, while a tick which appeared in a new position was added to the sketch and considered to be recently well-engorged. This method provided two types of information: the times of falling of the engorged females from their hosts, and the times when ticks became sufficiently engorged to be easily visible. The hosts were examined at two-hour intervals from 6.30 a.m.-6.30 p.m. for three days. It seemed that the ticks remained on their hosts for several hours after becoming well-engorged (see Appendix) but it is possible that some engorged and fell without being observed, especially during the night.

On the occasions of most visits to the shed, the air temperature in the shade and the general weather conditions were noted (Table 16).

Table 16 - Records of Weather, and Air Temperature in the Shade, during the Fort Willshire Observations.

Time	4th May		5th May		6th May	
	Temp.	Weather	Temp.	Weather	Temp.	Weather
6.30 a.m.	7°C	Clear	9°	Raining	10°	Small clouds
8.30	25°	Bright	13-15°	Occasional sunshine.	16°	Thin cloud
10.30	24°	Bright	13°	do.	21°	Sunny.
12.30 p.m.	19°	Dull	13°	Raining	23°	Bright
2.30	18°	Dull	15°	Clear	22°	-
4.30	16°	Dull	13°	Clear	18°	-
6.30	-		13°	Clear	-	-

Results/.....

Results.

The data obtained are shown in Tables 17, and 18. It seems that more ticks fell by day than during the night as one would expect if the pattern of tick-fall were similar to that observed in B. microplus by Hitchcock (1955a). However it is possible that the present data are biased by the fact that fewer observations were made during the night (see above).

Table 17 - Numbers of Female Ticks Recorded as Falling by Night and during the Following Day.

Host	Date	Night	Day
A	4 May	3	12
	5 "	4	5
	6 "	1	9
B	4 "	3	17
	5 "	11	6
	6 "	0	8
Totals		22	57

Table 18 - Numbers of Ticks recorded as Attaining Full Engorgement and Falling at Different Times.

Host	Date	a.m.			p.m.								
		6.30	8.30	10.30	12.30	2.30	4.30	6.30					
A	4 May	(7)	10	(5)	0	(1)	0	(0)	1	(1)	1	(1)	
	5 "	(3)	2	(2)	1	(0)	0	(1)	0	(0)	0	(0)	2
	6 "	(6)	5	(1)	3	(2)	0	(0)	0	-	1	-	0
B	4 May	(11)	12	(6)	2	(1)	1	(2)	1	(1)	1	(0)	-
	5 "	(2)	1	(2)	3	(0)	0	(1)	1	(0)	1	(0)	0
	6 "	(4)	6	(1)	0	(1)	0	(0)	0	-	2	-	0
Totals		(33)	36	(17)	9	(5)	1	(4)	3	(2)	6	(1)	2

During the day more ticks fell in the period 6.30-8.30 a.m. than during any other two-hour period (Table 18). Furthermore the numbers of ticks becoming well-engorged, but not falling, during the night and those dropping in the first two hours of the day were very similar and this suggests that the same ticks were involved. Thus it appears that most of the ticks engorging during the night had fallen from the hosts before 8.30 a.m.

Ticks continued to become well-engorged during the day and the data in Table 18 would suggest that the numbers of newly-engorged females decreased as the day progressed, while the ticks falling during the day provided a different pattern. However the numbers involved are small and this may have encouraged the observer to record as well-engorged ticks which were not really thus. In any event there does appear to be minimum tick-fall during the period 10.30 a.m. - 12.30 p.m.

Lest it be assumed that all ticks falling dropped of their own accord it must be mentioned that some were seen to be dislodged by the scratching activities of the bullocks. The beasts were able to rub or to lick most parts of their body surfaces. They scratched mainly while they were standing idle and not feeding, and, it seemed that they were more inclined to scratch when the weather was warm than when conditions in the shed were cool.

(ii) Host Activity and Tick-fall.

At Mount Pleasant on 17th and 18th April 1958, some
continuous/.....

continuous observations were made of the falling of ticks from a freely-ranging cow and notes were made on the activities of the host. The cow was observed in the morning when large numbers of ticks were available for falling. During almost the whole of the observation periods the host wandered in unshaded places and the ticks fell on grass. The animal was observed from a distance of about three metres.

Table 19 - Numbers of Ticks Seen to Drop from an Untethered Host.

Date	Time.a.m.	Period	Cow's Activities	Ticks falling
Apr. 17	7.50- 8.15	Mins. 25	Moving about quietly.	2?
	8.15- 9.00	35	Standing still or lying.	1?
	9.00- 9.15	15	Cow milked.	0?
	9.30-10.30	60	Cow watered, driven into field where actively walked and fed.	24
18	9.00- 9.35	35	Grazing quietly.	2
	9.35- 9.45	60	Milked	0?
	9.45-10.00	15	Actively feeding on cut grass and drinking.	10
	10.00-10.10	10	Walking and feeding.	4
	10.10-10.30	20	do.	0
	10.30-10.40	10	do.	2

(? = doubtful observation)

The data is shown in Table 19 and all the ticks referred to there fell of their own accord, i.e. they were not rubbed off by the host. Few ticks fell while the host was lying down, standing still, or grazing

quietly/.....

quietly. On the other hand ^{many} ticks dropped when the cow drank water and fed voraciously on cut grass, or when it wandered and fed 'actively' in the fields. It is noteworthy that the time of the morning when most ticks fell was earlier at Fort Willshire, as was the first watering and feeding of the day. Indeed there does seem to be a correlation between tick-fall and host activity, but whether the operative factors are mechanical or physiological is another matter.

Some casual observations of scratching activity of cattle were made at various times at Mount Pleasant. It was noticed that freely-ranging cows scratched while in sunlight e.g. against fences, or in the shade e.g. against trees or bushes. Most of the ticks rubbed off were well-engorged but at least one half-engorged tick was dislodged, which shows that it is not only the ticks which are ready to drop which are rubbed off by the host.

(iii) Climatic Conditions and Tick-fall.

Between 9.30 & 10.30am. on 17th April, while the cow was in the sunshine, nineteen ticks fell from the sunny side of the beast and only three were seen to fall from a shady side. This was suggestive and on the following day more detailed observations were made.

From 9.00 - 10.40 a.m. on 18th April the cow was watched alternately from left and right sides for ten-minute periods for each side. It was noted whether ticks fell from sunny or shaded sides of the animal, or a side which was shaded but had recently become sunny, or vice versa. The following results were obtained:-

sides/.....

Sides sunny for more than a minute..... 6 ticks fell;

Sides sunny, but shaded less than

1 minute before 6 ticks fell;

Sides shaded, but sunny less than

1 minute before 6 ticks fell;

Sides shaded for more than a minute No ticks seen
to fall.

It appears that the engorged females fell mainly from sunny sides, or from sides which had been recently sunny. Clearly climatic factors do affect the issue, but whether or not the effect is direct remains obscure. The physiology of the host skin may be the ultimate factor.

(iv) Possible Effects of Tick-Fall on the Distribution of Larval Clusters.

In a previous section it was suggested that engorged females of B. decoloratus cannot wander more than a few metres from the places where they initially fall from their hosts and that in some circumstances the ticks cannot move at all. Thus the distribution of the larval clusters may be considerably affected by the distribution of hosts and the dropping behaviour of engorged female ticks.

It appears that engorged females of B. decoloratus drop from their hosts in relatively large numbers at certain times of day. This could account for the patchiness of the distribution of larval clusters which was noted at Trent (see II. 4). If there is a tendency for many ticks to fall within a short period, a single well-infested host could be the source of a patch of larval clusters; also a gregariously-grazing herd of cattle could provide a localized infestation of larval clusters.

The/.....

The Mount Pleasant observations suggest that the engorged female ticks may drop preferentially in the more open situations, where the host is not shaded. On the other hand it is evident that cattle can dislodge well-engorged ticks in shade as well as in sunshine. Thus it is possible that hosts which are much irritated by parasites drop considerable numbers in shady places as well as in the open situations.

The results of previous workers (see above) and the data obtained in the present investigation suggest that the most female ticks perform their final engorgement during the night, and fall off when the hosts become active the following morning. Observations at Trent by the present author, and also by the owner of that farm, indicate that the cattle there usually graze in the open grassy places in the first few hours of daylight and only settle down in the shade of trees during the mid-period of the day. If this is the case then it is possible that at Trent most engorged females of B. decoloratus fall in the unshaded grassy places, even if the cattle do scratch while in the shade at midday, since then there are probably few well-engorged ticks available for falling. The rarity of larval clusters in well-shaded situations, as noted in the surveys, may have been caused by such a combination of the behaviour of female ticks and of their hosts.

5. CONCLUSIONS.

(i) Although larvae will often migrate vertically as they move from their hatching site, and form a cluster immediately above it, in some circumstances these ticks will migrate horizontally before moving to the
vegetation/.....

vegetation tips. Light seems to be an important factor determining whether the larvae will move vertically or horizontally.

(ii) Engorged female ticks may be unable to wander because they have fallen on their dorsa and cannot right themselves.

(iii) Usually engorged females are able to right themselves, to walk, to orient, to burrow and settle down i.e. they are able to choose a settling-place to some extent. In places where there are not many obstructions to progress, the ticks may settle a metre or more away from the spots where they fall. It does not seem likely, however, that they are able to travel more than about six metres from their original positions.

(iv) Time spent in wandering is sometimes reduced by night-time conditions and the relatively extreme climate of the mid-period of the day.

(v) Normally settling occurs when the tick is in the shade and the substratum is penetrable so that the female can bury itself more or less completely. (Other factors such as temperature probably also affect the issue.) The presence of a rigid object such as a stone may encourage burrowing or settling.

(vi) Wandering and normal settling may be impaired by prolonged exposure to direct sunlight. A tick 'exhausted' by such exposure may settle down without burying itself.

(vii) After burrowing and when a tick has remained settled for several hours or days, it may continue

wandering/.....

wandering either before or after the onset of oviposition. Exposure to free water or to very high temperature appear to be possible disturbing factors although perhaps mechanical interference also causes ticks to move from settled position.

(viii) Female ticks apparently engorge usually during the night and fall from the host in the first few hours of daylight, when the animal is active, and preferably while it is exposed to direct sunlight.

(ix) In some circumstances the host will scratch or rub off some of the well-engorged female ticks, before they are ready to drop of their own accord.

(x) It appears that all the above-mentioned aspects of the behaviour of larvae and engorged female ticks may affect the distribution or relative abundance of larval clusters in different types of field situations, but the more important possibilities seem to be the following:-

- (a) The horizontal scattering of larvae away from their hatching sites may mean that larval clusters seldom form in certain types of field situations although they develop there;
- (b) The wandering of engorged female ticks from areas where there is little obstruction to movement and conditions are not well-suited for settling may mean that females seldom settle in certain places although conditions there may be favourable to survival.
- (c) Frequent wandering of engorged female ticks during their oviposition periods may mean that there/.....

there are few compact larval clusters in a place which is climatically favourable to the development of larvae even, or particularly, if the eggs were laid in a single mass.

- (d) Combination of a pattern of attainment of full-engorgement and the distribution and behaviour of the hosts (including their scratching activities) at different times of day may mean that engorged females seldom fall in certain types of field situations.

Some of the above may account for the rarity of larval clusters of B. decoloratus in places with sparse vegetational cover or in well-shaded places, but further investigations are needed to establish any of the suggested relationships between the behaviour of ticks and their distribution in micro-climatically different field situations.

Chapter V - SUMMING-UP.

One of the most obvious features of the autumn surveys was the patchy distribution of larval clusters of B. decoloratus which was apparently unrelated to micro-climatic differences. It is clear that cattle are the main or only host of this species in the areas considered (see also Arthur, 1960) and that this patchy distribution was partly because cattle had been excluded from certain camps for several months. On the other hand the patchiness within camps appears to be due to the behaviour of the engorged female ticks as well as the distribution of the hosts. At some times of the day relatively large numbers of engorged females of B. decoloratus fall more or less simultaneously. Thus many ticks fall within a short distance of one another in places where an infested cow or herd grazes at the times of maximum tick-fall, and subsequently patches of larval clusters may appear in such places.

Falling of female ticks follows a similar pattern in all the species so far investigated which belong to two very different genera, namely, Boophilus and Ixodes (e.g. Balashov, 1954; Hitchcock, 1955a). Thus one would expect that all the species considered in the present investigation might show patchy distribution of larval clusters. In fact no such patchiness was observed in the cases of R. evertsi and A. hebraeum, possibly because the adult females of these species did not occur in large numbers on their hosts. They were certainly not very numerous on cattle. The distribution of larval clusters of I. pilosus was not remarkably patchy perhaps because the infestation of the one farm harbouring this species was so great that
almost/.....

almost all the microclimatically favourable places there had accumulations of the clusters.

The main hosts of I. pilosus seemed to be other than cattle probably 'bushbuck'. These buck are reputed to be sometimes heavily-infested with adult females of this species and spend much of their time in well-shaded situations where the larval ticks were so abundant. But the distribution of larvae of I. pilosus was clearly not only determined by host distribution but also by direct effects of microclimatic conditions on the survival of the engorged female ticks and eggs. Observation of these 'pre-larval stages' in microclimatically distinct plots show that the absence of the larval clusters from open situations, for instance in autumn, was probably because in the previous weeks or months such places had been microclimatically unfavourable to the earlier stages. After the cool winter months the clusters were found in a wider range of situations.

Microclimatic conditions also had direct effects on the three other species. A farm, where in autumn a wide variety of field situations had been infested with larval clusters of B. decoloratus, was found in the following spring to be free of such ticks in all except the warmest situations. The plot investigations made in the same year confirmed the view that the restricted spring distribution was because the cooler and damper situations were microclimatically unfavourable to early spring development of larvae.

It is possible that during some periods of drought no larval clusters of any species will be found in

unshaded/.....

unshaded situations. The plot data show that in a drought lasting several weeks during November/December prelarval ticks survived only in the shady places, and it is likely that in such circumstances larval ticks would have a similarly limited distribution.

There appear to be some discrepancies when the picture of larval cluster distribution obtained in the surveys is compared with that emerging from the plot investigations. One at least seems to be due to factors other than the direct effects of climate on the survival and development of prelarval stages, namely the fact that well-shaded situations were favourable to the development of larvae in the autumn of 1958 but no larval clusters other than those of I. pilosus were found in the surveys of such places during the autumn of the previous year. This state of affairs is particularly remarkable in the case of B. decoloratus which had been quite abundant in unshaded areas on one of the farms surveyed. Some observations on the behaviour of engorged females and larvae of B. decoloratus suggest possible explanations.

After hatching and tanning the larvae migrate from their hatching-sites. In open situations where there is grass which is not short-cropped they migrate to the tops of grass more or less immediately above their original positions. On the other hand it seems that larvae hatching under bushes migrate horizontally until beyond the shade of such vegetation. Thus perhaps larvae in well-shaded situations such as tree clumps or forests may tend to scatter away from their hatching sites and so fail to form recognisable clusters.

The/.....

The behaviour data further suggest that, if engorged females of B. decoloratus fall in shaded places not many metres away from open situations, these ticks may, under some conditions, be inclined to walk until they eventually arrive at more exposed areas. Even if the females do not manage to leave the well-shaded places, no larval clusters will form if the ticks continue frequently to wander during their oviposition periods.

Perhaps the most probable explanation for the dearth of larval clusters of B. decoloratus in well-shaded places is that the engorged females of this species seldom fall in such situations. It was found that the females attained complete engorgement mainly during the night, and that most dropped while their hosts were actively feeding and exposed to direct sunlight in the first few hours of daylight. Some observations on behaviour of cattle suggest that the dropping of the female ticks would usually take place while the hosts are in the open grassy areas because this is where the cattle are wont to be in the first part of the day. It seems that the beasts sometimes move into shady places later in the day, but at that time there are probably few fully-engorged female ticks remaining attached, so that even if the hosts scratch themselves, the numbers falling in such situations will probably be small.

There is at least one factor not dealt with in the present investigation which may considerably affect the distribution of larval clusters, namely the
activities/.....

activities of tick predators. During some periods almost all the engorged female ticks in certain field plots were removed by animals, probably rodents, but it is likely that learning on the part of the predators was responsible for this high predation in places where ticks were regularly introduced. Nevertheless the effects of predation on the distribution of larval clusters in microclimatically different field situations may be worthy of investigation.

It is of interest to consider possible practical applications of the type of information obtained in the present study. In fact only one suggestion can be made at this stage, - a suggestion relating to the annual program of cattle-dipping in the Eastern Cape Province. In the vicinity of Grahamstown and the town of Bathurst cattle are dipped or sprayed with acaricide usually once a week during the warmer months of the year when ticks are obviously numerous, and less frequently during the winter when there are few ticks to be seen on the beasts. The work of Snowball (1957) and Norris (1957) on the ecology and control of B. microplus in south Queensland suggests that control of B. decoloratus may be more effective if the start of more intensive dipping is timed to coincide with the first appearance of larvae in spring rather than with increased infestation of cattle with well-engorged females, as is at present the case. The results suggest that planning of the dipping program might be assisted in the following way. A fence could be erected around a relatively warm patch of ground, such as on a north-facing slope with little vegetational cover/.....

cover, where there are places in which engorged females of B. decoloratus might settle. (The presence of stones would probably be useful in this latter respect). During the winter the stock-inspector or individual farmer could occasionally 'seed' this plot with engorged females of B. decoloratus and as soon as larvae appear there at the vegetation tips, intensive dipping of cattle could be restarted since this would be the time when the first spring larvae would appear in the field.

No further practical suggestions can be made at this stage. When the importance of the ranging behaviour of cattle has been assessed, it may be possible to discuss further control measures for B. decoloratus. For instance one might suggest that well-shaded situations in the Eastern Cape should be sprayed with acaricides during periods of drought, when the non-parasitic stages of this species are only able to survive in such situations, but such a measure might be a waste of effort if hardly any ticks fall in the shady situations because the cattle are in the open at times of peak tick-fall. In the cases of the three species other than B. decoloratus it is necessary to investigate the ecology of non-parasitic nymphs and adults before similar control measures can be intelligently discussed.

REFERENCES.

- ACOCKS, J.P.H. (1953) - Veld Types of South Africa.
Botanical Survey of S.A. Memoir No. 28 .
- ARTHUR, D.R. (1948) - On the egg of the tick, Ixodes ricinus, L. Parasitology 39:53-60
- _____ (1960) - Ticks, A monograph of the Ixodoidea. Cambridge University Press .
- BALASHOV, Yu.S. (1954) - Peculiarities of the day and night rhythm of the dropping of engorged females of Ixodes persulcatus from cows. Abstract in Rev. appl. Ent. 43:146
- DETHIER, V.G. (1957) - Sensory Physiology of blood-sucking arthropods. Journal of Experimental Parasitology 6:68-122
- GEIGER, R. (1950) - The climate near the ground. Harvard.
- GRAY, W.J. - A preliminary report on some field studies of tick biology. Departmental report 1957, Veterinary Research Laboratories, Mazabuka, N. Rhodesia .
- HITCHCOCK, L.F. (1955 a) - Studies on the parasitic stages of the Cattle Tick, Boophilus microplus (Canestrini). Aust. J. Zool. 3:145- 55
- _____ (1955 b) - Studies on the non-parasitic stages of the Cattle Tick, Boophilus microplus (Canestrini). Aust. J. Zool. 3:295-311 .
- JOHNSON, N.K. & DAVIES, E.L. (1927) - Some measurements of temperature near the surface of various kinds of soils. Quarterly Journal of the Royal Meteorological Society. 53:45-59 .
- KNEISIN, E.M. & LAVRENNENKO, L.E. (1956) - Duration of blood-sucking and daily rhythm of feeding and dropping in females of Ixodes ricinus, L. Abstract in Rev. appl. Ent. (1957). 45. 211
Zool. Zh. 35: 379-383

- KOSLOWSKI, S. (1953) - Preliminary report on the quantitative relations prevailing in the populations of the tick, Ixodes ricinus, L. Ekol. Polska. 1 (3) .
- KRIJGSMAN, B.J. (1937) - Reiphysiologische Untersuchungen an Blutsaugenden Arthropoden im Zusammenhang mit Ihrer Nahrungswahl III Teil: Versuche mit Zecken. Arch. Neerl. de Zool. II:401- 13
- LEES, A.D. (1946) - The water balance in Ixodes ricinus, L and certain other species of ticks. Parasitology 37:1-20
- _____ (1947) - Transpiration and the structure of the epicuticle in ticks. J. exp. Biol 23:379
- _____ (1948) - The sensory physiology of the sheep tick, Ixodes ricinus, L J. exp. Biol 25:145-207
- LEES, A.D. & A.MILNE (1951) - The seasonal and diurnal activities of individual sheep ticks (Ixodes ricinus, L) Parasitology 41:189-208.
- LOUNSBURY, C.P. (1905) - Reprint ^{or} ^{75th Meeting A} of the British Association for the Advancement of Science (S.A.) 282- 91.
- MACLEOD, J. (1932) - Bionomics of Ixodes ricinus, L, the sheep tick of Scotland. Parasitology 24:382.
- _____ (1934) - Ixodes ricinus in relation to its physical environment I. Influence of climate on development. Parasitology 26:282.
- MASON, H.L. & J.H. LANGENHEIM (1957) - Language analysis and the concept environment. Ecology 38:325
- NEITZ, W.O. (1956) - A consolidation of our knowledge of the transmission of tick-borne diseases. Onderstepoort J. Vet Res. 27:115-.63.

- NEITZ, W.O. & R.A.ALEXANDER (1945) - Immunization of cattle against heartwater and the control of tick-borne diseases, red-water, gallsickness and heartwater. Onderstepoort J. Vet Sci. 20:137-158.
- NORRIS, K.R. (1957) - Strategic dipping for control of the Cattle Tick, Boophilus microplus in south Queensland. Aust. J. agric. Res. 8:768-787
- PHILIP, G.B. (1937) - Six years intensive observation on the seasonal prevalence of a tick population in Western Montana. Public Health Reports, U.S. Treasury Department 52:16-22.
- PICHÉ, A. (1872) - Note sur l'atmometer, instrument destinee à mesurer l'evaporation. Bull. Ass. Sci. France 10:166-167.
- RICHARDS, L.A. (1928) - Usefulness of Capillary potential to soil-moisture and plant investigations. J. agric. Res. 37:719-742.
- SNOWBALL, G.J. (1957) - Ecological Observations on the Cattle Tick, Boophilus microplus. Aust. J. agric. Res. 8:394-412.
- STAMPA, S. (1959) - Tick paralysis in the Karoo areas of South Africa. Onderstepoort J. Vet. Res. 28 169-227.
- THEILER, G. (1949) - Zoological survey of the Union of South Africa: Tick Survey. II - Distribution of Boophilus (Palpoboophilus) decoloratus, the Blue Tick. Onderstepoort J. Vet Sci. 22:255.
- UVAROV, B.P. (1931) - Insects and climate, Trans. Ent Soc. Lond. 79:1-247.

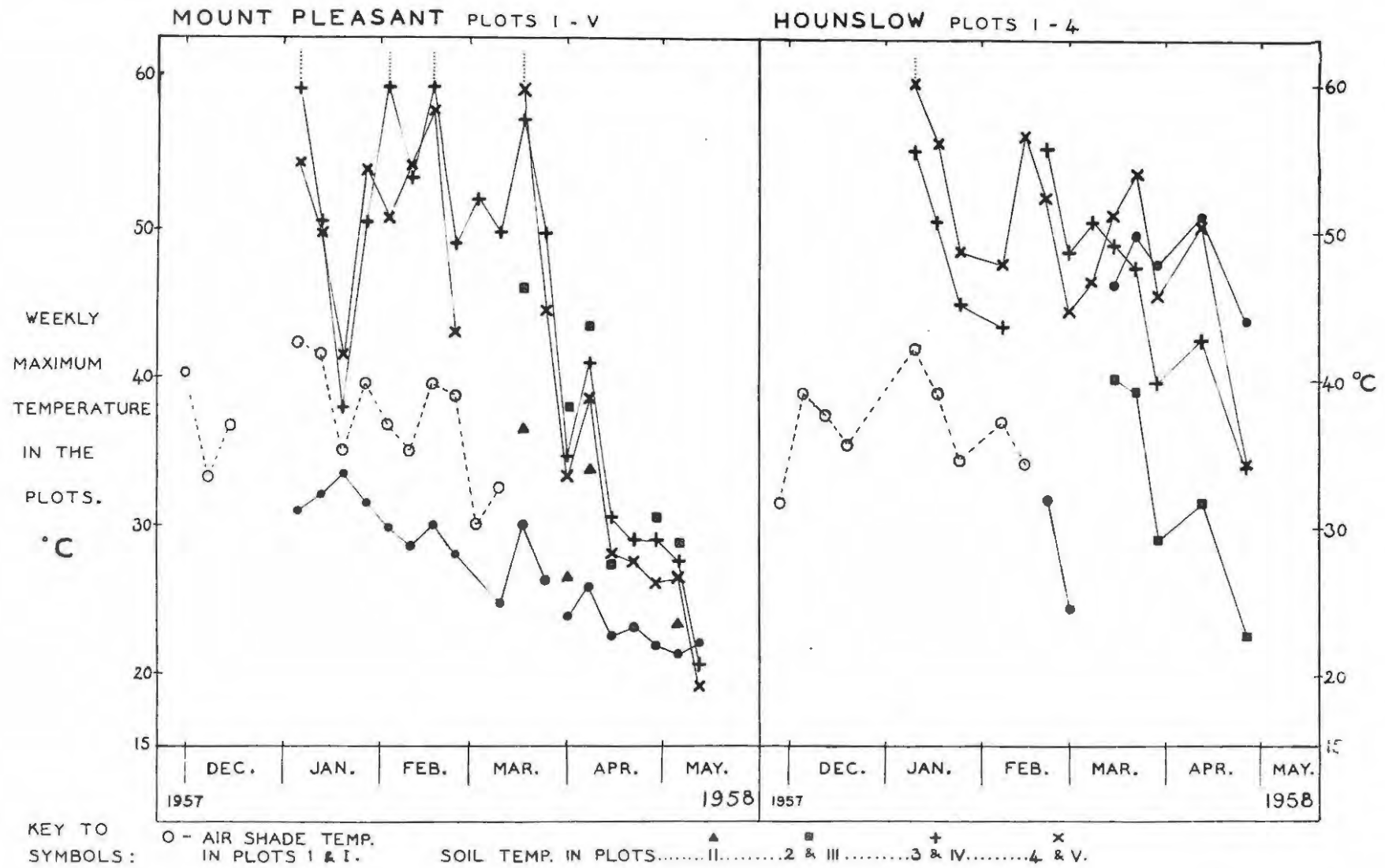
- WHITEHEAD, G.B. & BAKER, J.A.F. (1960) - Toxaphene
* resistance in the Red Tick, Rhipicephalus
evertsi, Neu. in South Africa.
Veterinary Record 72:566.
- WIGGLESWORTH, V.B. (1953) - The principles of Insect
physiology. Methuen.
- WILKINSON, P.R. (1953) - Observations on the sensory
physiology and behaviour of larvae of the
Cattle Tick, Boophilus microplus (Canestrini)
Aust. J. Zool. 1:345-356.
-
- (1957) - The spelling of pasture in
cattle tick control. Aust. J. agric. Res. 8:413

* = not seen.

APPENDICES.

- A. Weekly maximum temperatures recorded in the surface soil of the plots at Mount Pleasant and Hounslow.
- B. Weekly maximum and minimum temperatures recorded in the air about 5 cms above the plot soils, and also those recorded on the thermohygrograph among the farm buildings. - MOUNT PLEASANT.
- C. Weekly maximum and minimum air temperatures recorded at HOUNSLOW.
- D. Patterns of degree of soil saturation as calculated from samples collected from the plots on a farm on the same day, - at various times of the year.
- E. Patterns of evaporation and wind in the plots on each of the two farms (Mount Pleasant and Hounslow).
- F. Comparison of soil temperatures in the 'corresponding plots' of Mount Pleasant and Hounslow. Values which on one farm are higher than those recorded on days soon before and after on the other farm are underlined, since these show that higher temperatures occurred in the plot of the former farm during a comparable period of a few days.
- G. Comparison of percentage soil saturation in the 'corresponding plots' of Mount Pleasant and Hounslow.
- H. Table to show that females of B. decoloratus sometimes remain attached to the host for several hours after becoming 'well-engorged'.
- I. One afternoon's observations of the behaviour of an engorged female of B. decoloratus (Tick S), to show that the tick tended to walk in a certain direction ('with sun on the right') and that it may have been orienting towards a tree a few metres away.

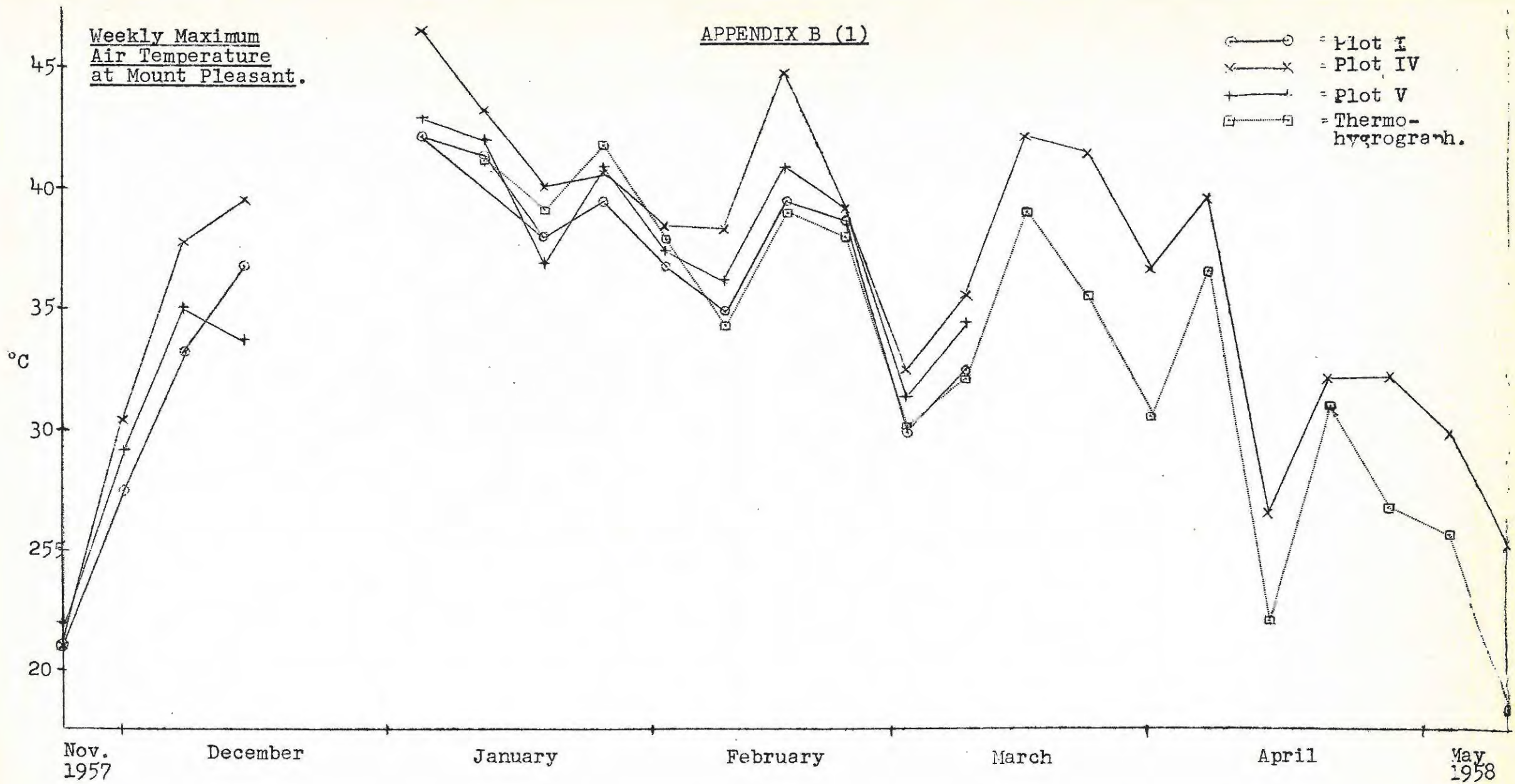
APPENDIX A.

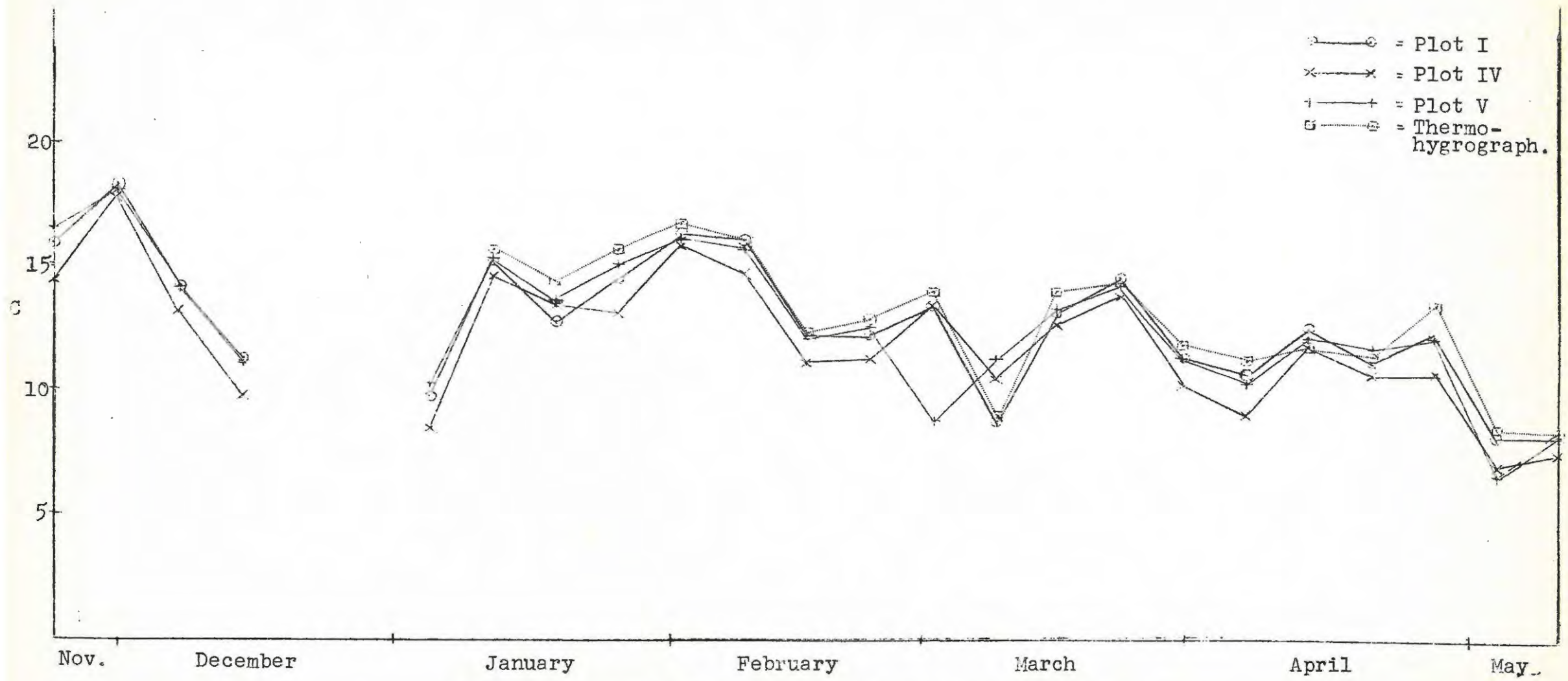


Weekly Maximum
Air Temperature
at Mount Pleasant.

APPENDIX B (1)

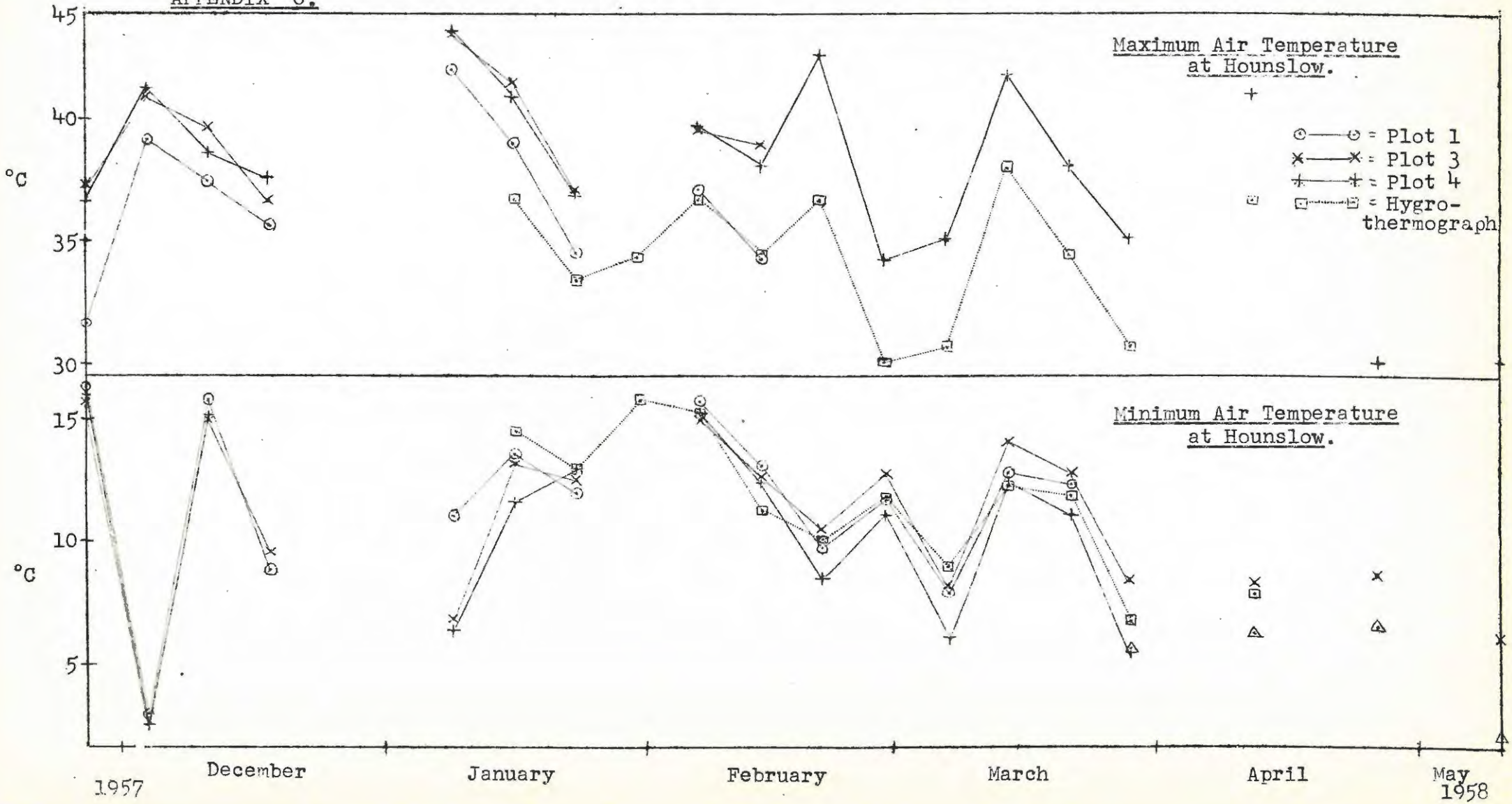
- = Plot I
- ×—× = Plot IV
- +—+ = Plot V
- = Thermo-
hygraph.



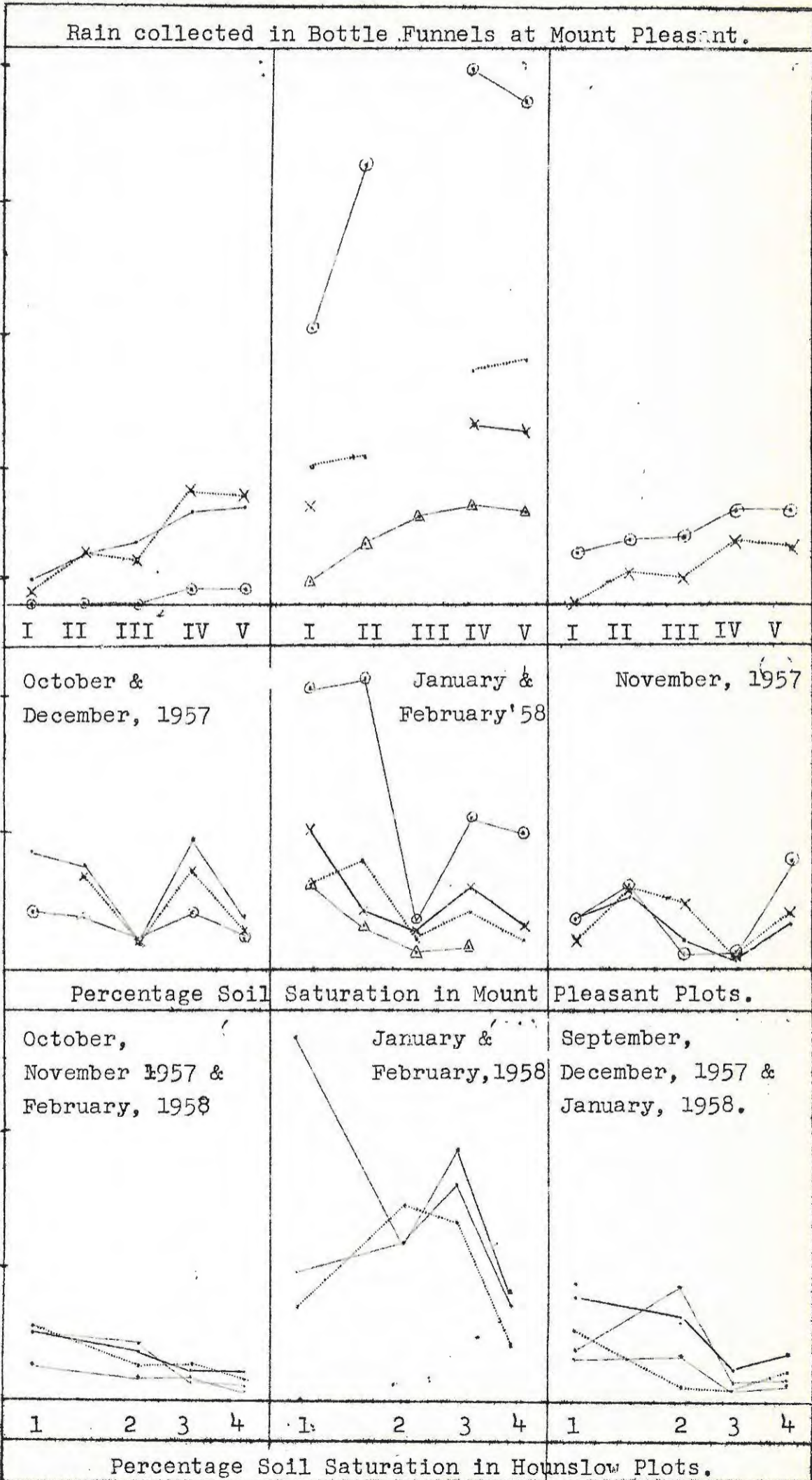


Weekly Minimum Air Temperature at Mount Pleasant 1957/58.

APPENDIX C.

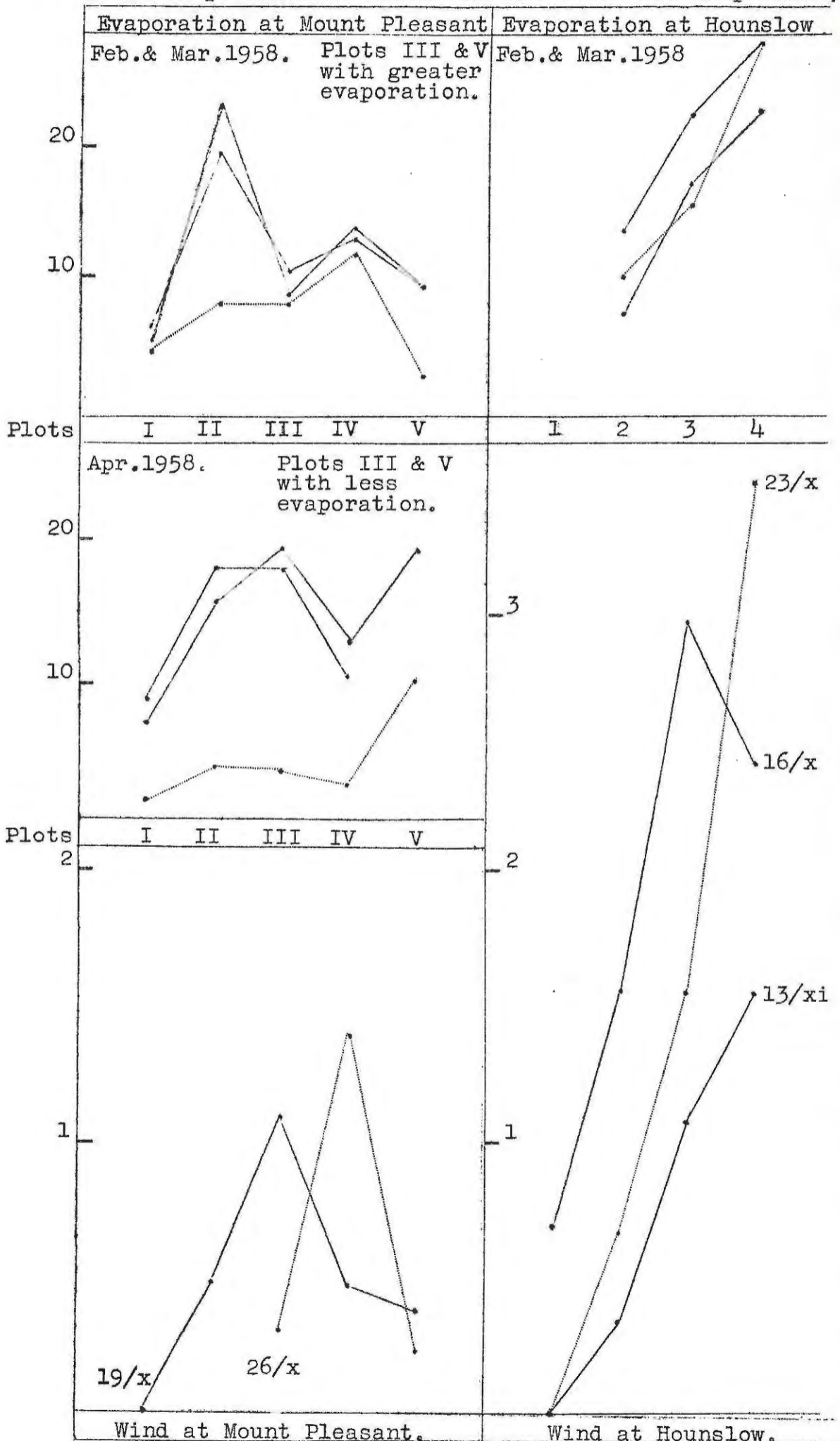


APPENDIX D.



APPENDIX E.

(Evaporation measured in inches along the length of the Piché evaporimeters. Data for two farms not comparable)



Wind strength based on the reciprocals of the time (seconds) for the Anemometer to register a complete revolution on its dial.

APPENDIX F.

Between Farm Comparison.

Maximum Soil Temperatures.

Dates.	1	I	2	III	3	IV	4	V
5/1		31.0				60		54.4
9/1					55.25		60	
12/1		32.0				50.25		49.75
16/1					50.5		55.8	
19/1		33.6				38.0		41.5
23/1					45.0		48.4	
26/1		31.5				50.5		54
2/2		29.8				60+		50.8
6/2					43.6		47.5	
9/2		28.4				53.6		54.3
14/2					39.5		56.6	
16/2		30.1				61.0		48
20/2	31.8				55.5			
23/2		28.0				48.9		
27/2	24.3				48.6			
2/3						52.0		
6/3					50.4			
9/3		24.75				49.8		
14/3	46.2		39.7		48.9		50.9	
16/3		30		45.75		57.5		60+
21/3	49.75		39.2		47.6		53.75	
23/3		26.2				49.8		44.5
28/3	47.8		29.0		39.4		45.4	
30/3		23.8		38.0		34.75		33.25
6/4		25.8		43.25		40.75		38.5
11/4	51.0		31.6		42.6		50.3	
13/4		22.8		27.75		30.6		28.0
20/4		23.0				28.9		27.7
25/4	44.0		22.3		33.8		33.9	
27/4		21.75		30.4		29.0		26.1
5/5		21.3		28.8		27.5		26.5
9/5	44.0		23.2		29.25		29.5	
11/5		22.0				20.6		19.0

APPENDIX G.

Between-Farm Comparison.

Percentage Saturation of Soil Samples collected in the
Several Plots.

Dates	1	I	2	III	3	IV	4	V
19/10		33		53		16		5
23/10			18		16		<u>12</u>	
26/10		17		4		19		8
30/10	10		5		5		3	
3/11		<u>19</u>				<u>10</u>		2
5/11	6		<u>7</u>		2		4	
10/11		<u>7</u>		2		3		<u>17</u>
13/11	5		4		<u>4</u>		2	
17/11		4		<u>10</u>		2		<u>8</u>
20/11	9		9				1	
24/11		7		4		2		<u>7</u>
29/11	6		3		1		1	
2/12		8		<u>4</u>		<u>8</u>		4
4/12	10		2		2		4	
8/12		<u>72</u>		<u>72</u>		<u>40</u>		<u>49</u>
11/12	15		13		5		7	
15/12				3		<u>14</u>		5
19/12	7		17		3		4	
5/1		<u>61</u>		<u>41</u>		<u>46</u>		<u>77</u>
9/1	54		23		37		16	
12/1		12		4		8		4
16/1	<u>44</u>		<u>91</u>		13		15	
19/1		<u>41</u>		7		23		<u>20</u>
24/1	14		<u>29</u>		<u>26</u>		8	
26/1		15		28		21		<u>32</u>
30/1	<u>18</u>		12		5		7	
6/2	10		7		4		4	
9/2		<u>20</u>		5		<u>12</u>		<u>6</u>
13/2	10		8		3		2	
16/2		<u>88</u>		<u>46</u>		<u>34</u>		<u>68</u>
20/2	19		23		32		14	
23/2		12		2		3		
27/2	6		6		3		2	
3/3		65		53		60		49

Appendix H. Number of Marked Ticks Remaining Attached to a Host after becoming well-engorged at Different Times.

Date 1958	Time	Newly-engorged ticks.	Numbers of marked ticks found at Morn.Noon.Even- Night. Noon.Even- ing. ing.
1 May	1.30 p.m.	(25 ticks removed)	
	5.30	6	..... ? ... 4
2 May	9a.m.	120	..... 4 .. 3 ... 1 ... 1
	1p.m.	13	...10 ... 1
	5p.m.	2	..... 0
3 May	9a.m.	60	..... 27...19
Date	Time	Newly engorged ticks	Morn.Later.After-Even-Night.Morn.Late noon. ing.
6 May	6.30 p.m.	1	..... 1 1...0
	10.30	8	..... 8...1
7 May	6.30 a.m.	12	..... 2 0
	10.30	4	..... 2 ...2... 2 2
	2.30 p.m.	14	...9... 8 7
	6.30	0	
8 May	10.30	1	..... 1
	8.00 a.m.	15	..... 0?
	12.30 p.m.	5	..... 2... 2 2
9 May	6.30	1	... 1 1...1
	12.30 a.m.	0	
	7.00	9	..... 4

Appendix I. - Observations on the Behaviour of Tick(S.)

July 1st.

- 2.10 p.m. Placed facing east; makes a half-turn left towards the sun and then right away from the sun; now walking fast;
- 2.10 " walking with sun on right but both eyes in the shade;
- 2.15 " walking 'excitedly' with feet of left side on a leaf; now trying to get under the leaf;
- 2.20 " under the leaf and debris and then emerging from the other side;
- 2.25 " walking with the sun on right; movements rather frantic;
- 2.30 " sun on right; upward movement and facing more towards the sun;
- 2.35 " apparently accidentally comes upon a grass tuft: makes slight movement to get under it and then moves away;
- 2.40 " sun on right back; appears to keep eyes just in shade; walking now towards the sun perhaps in response to slight shade provided by dry grass;
- 2.45 " tick on slope facing sun but does not walk up the slope but along it with the sun on right; now walking ineffectually in loose dust;
- 2.50 " tries to climb upwards but desists and continues along the slope with sun on right back;
- 3.00 " in shade of a fairly large plant, still walking with sun on right perhaps because of the 'shape' of the substratum; burrowing into dry debris and tiny pebbles while a spot of sunlight on posterior part of the tick.

3.10/.....

- 3.10 p.m. moving away from 'burrow' with sun on right although the tick is still in shade;
- 3.15 " attempting to burrow into a dry grass tuft but soon moving away;
- 3.35 " still with sun on right but in dappled shade; substratum of dry debris; now attempting to burrow;
- 3.50 " in full sunlight with sun on right;
- 4.05 " walking away from sun uphill; now walking zigzag;
- 4.10 " zigzagging with sun on right; turned about so that sun on left back;
- 4.15 " sun on right as tick walks uphill;
- 5.00 " moving slightly among crumbs of soil.

The movements with the sun on the right were probably mainly directed towards the tree to the west of the tick.

AKNOWLEDGEMENTS.

I am indebted to many people for their assistance, encouragement or hospitality, and some of these I would like to mention by name. Dr G. Theiler helped in many ways, but particularly in introducing me to the literature and in identifying tick material. Dr C. Tidmarsh kindly organised the loan of meteorological equipment from the Weather Bureau. The following farmers provided hospitality and every assistance:- M. Hart-Dyke (Trent), N. Purdon (Grandon), T.J. Lake (Seaview), J. Slater (Fort Willshire), G. Dell (Hounslow) and the late W. Chalmers (Mount Pleasant). Drs J.C. von Hille and E. McC. Callan spent much of their valuable time driving me to and from farms. Professor D.W. Ewer offered advice and criticism.

I would like to express appreciation of the services of the Rhodes University Library and the Jagger Library, University of Cape Town. Finally the Department of Agriculture and African Explosives and Chemical Industries must be thanked for the money which made the investigation possible.