THE PHENOLOGY OF AN ENCLOSED PASTURE AREA WITH SPECIFIC REFERENCE TO THE SOIL-VEGETATION INTERFACE

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Presented for the degree of Doctor of Philosophy of the University of Waikato, New Zealand.

Dedicated to those people who would have liked to have helped but were dissuaded from doing so.

....

"It must be admitted that the ecologist is something of a chartered libertine. He roams at will over the legitimate preserves of the plant and animal biologist, the taxonomist, the physiologist, the chemist and even the sociologist; he poaches from all of these and from other established and respected disciplines. It is indeed a major problem for the ecologist, in his own interest, to set bounds to his divagations."

A. Macfadyen (1957)

Animal Ecology: Aims and Methods

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GRAPH

ERRATUM

For *Altermetaponia rubriceps* Macq.

read *Inopus rubriceps* Macq.

ABSTRACT

Over a seven year period (1966-1972) a systematic survey was made of an enclosed pasture area on the campus of the University of Waikato, Hamilton, New Zealand. Areas of similar soil type and floral composition were used for comparison at Newstead and Tamahere. Comparisons are made with shorter-term studies at Newstead and in other countries.

None of the three sites had fertiliser applied during the survey period. Apart from sampling procedures, no vegetation was removed from Hillcrest, but Newstead and Tamahere were subjected to systematic mowing.

Seasonal and long-term fluctuations of populations were determined for all major faunal groups, together with seasonal and successional development of the flora.

Relationships between meteorological factors, faunal and floral composition have been subjected to computer analysis. Some correlations are suggested. The emphasis in the survey has been upon the fluctuations and relationships of groups rather than the precise responses of individual species to environmental variations.

Feeding experiments with fauna in the laboratory have helped to add to the knowledge of the trophic position of some New Zealand species.

The results of the survey show the effects of floral competition where Holcus lanatus, Bromus unioloides and Ranunculus sardous replace rosette and soft annual plants. The rate and sequence of succession are shown.

An adaptation of the Berlese extractor was developed to give indications of the vertical distribution of fauna.

Long-term change in faunal composition are not clearly indicated. Changes which do occur are mostly at the soil surface, reflecting the state of vegetation and litter.

As a result of the extended survey, it would seem that one of the most important influences in the ecology of light loam agricultural pastures is the quality of the soil/vegetation interface. When a litter layer is retained throughout the year, faunal numbers fluctuate less rapidly and to a lesser extent than in exposed short vegetation pastures. Basically, litter acts as an ecological buffer, dampens down extremes of microclimate change, and provides a greater number of niches for soil microfauna. Where vegetation removal does not occur, small low-growing plants and seedlings are suppressed. The smothering effects of the stems and leaves from taller plants maintain the dominance of perennial species.

SECTION 1 : INTRODUCTION

Every environment exercises certain demands on its inhabitants. Certain animals are favoured by the conditions existing in a particular place, others barely manage to survive, and some are debarred from that specific environment altogether. This is caused by the fact that the needs and the faculties of the various organisms differ. The more extreme the conditions, the stricter the selection, but at the same time, the more characteristic are the organisms which can survive in the given circumstances. The soil being in many respects such a highly specialised environment, an attempt is made to describe the selective influence of the soil in general and the effects of specific soil conditions upon the animals.

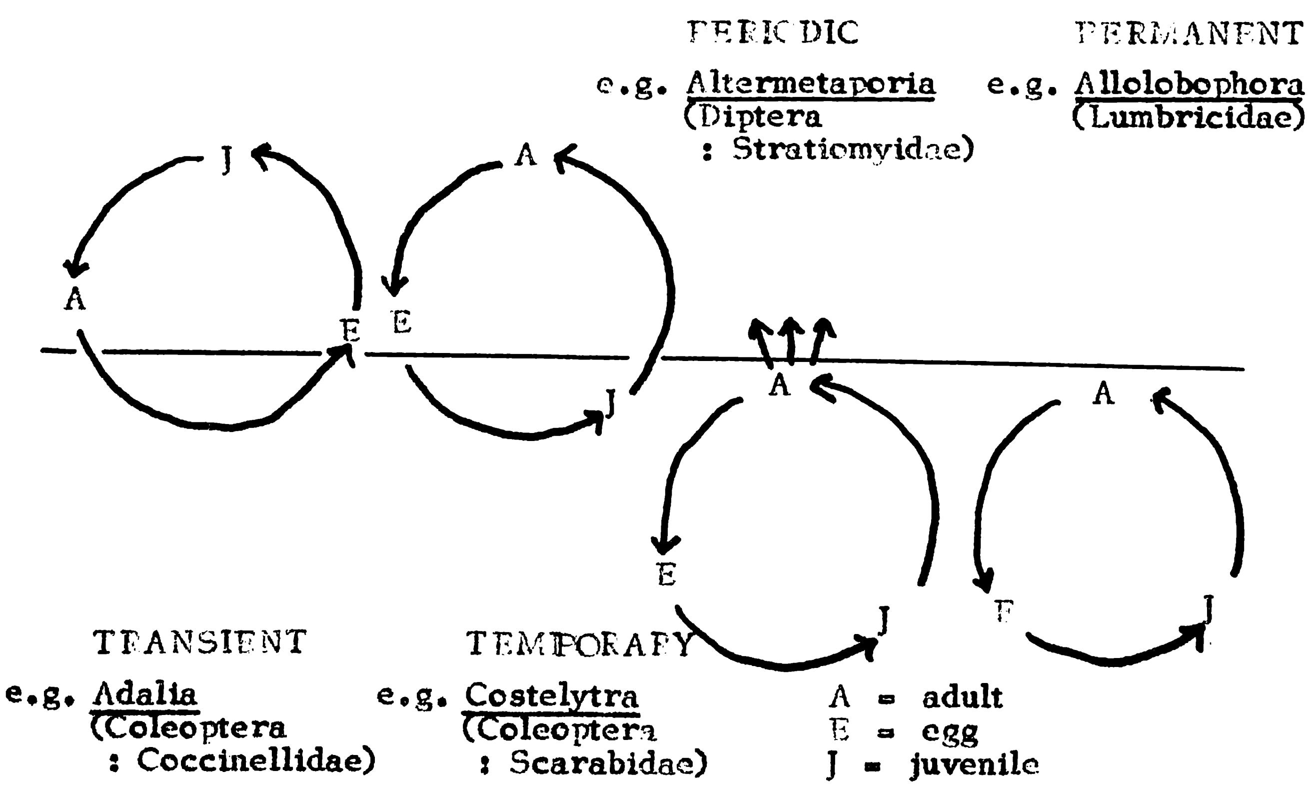
The definition of a soil animal as "one that lives in the soil", carries with it little intrinsic significance, for most of the major fauna have representatives which spend at least a part of their life-cycle in the soil. Not all of these animals have an equally close association with this environment. Some seek only a temporary refuge in the soil and can be considered at the most only marginal members of this community, for although their effect on a particular soil may be considerable, it is often localised and temporary.

A distinction can be made between temporary and permanent members of the soil fauna. To the former category belong insects that enter the soil as adults to escape unfavourable conditions above the ground, as, for example, the hibernating Coleoptera, Thysanoptera and Heteroptera. Also included in this temporary fauna are the insects which undergo part of their development usually as eggs and larvae in the soil. Diptera larvae are important members of this group. Both of these groups of temporary soil animals have been designated as 'geophiles' (Jacot, 1940), although it is probably important to distinguish between the inactive geophiles and those groups that are active members of the soil fauna at least for part of their life. Inactive geophiles include many adult insects which seek the shelter afforded by loose leaf litter and decaying logs lying on or partly embedded in the surface of the soil. For example, females of flower and grass thrips often descend into the leaf litter at the end of summer to live the winter there. A similar behaviour pattern is adopted by the adults of various plant bugs, for example, aphids, pentatomids. Many phytophagous beetles, particularly those belonging to the Chrysomelidae over-winter as adults and may be encountered from time to time in soil and litter samples. Because of their relative inactivity, these temporary members of the soil fauna make only a slight contribution at the most, to the soil ecosystem.

Many insects pass through a distinct stage, or stages of development in the soil, eventually to emerge as winged aerial adults and thus have a closer association with the soil than those just discussed. These forms may properly be classed as active geophiles. For the most part these insects belong to one of three major orders, namely, the Diptera, Coleoptera, and Lepidoptera, and since they are all holometabolous, the developmental stages concerned are the larvae and pupae. Insect pupae play little or no part in the soil ecosystem for they are relatively inactive. Insect larvae on the other hand are often of considerable importance as detritus feeders or carnivores, particularly where they occur locally in high densities.

These insect larvae occupy a special position in the soil community, for they are well adapted in body form, methods of locomotion, and feeding habits to life in the soil and yet they are transient because many of them will pupate and eventually leave the soil as adults with entirely different adaptations to aerial life. Ecologically speaking the main distinction between these geophiles and the permanent soil fauna is that in the former case immigration (as eggs laid in the soil) and emigration (as adult emergents) make a much greater contribution to population changes than they do in the latter. This is particularly true of those species that oviposit and emerge as adults at restricted times of the year.

Kevan's (1962) classification separates the inactive geophiles (transients) from the active ones, which are further grouped into 'periodic' and 'temporary' categories depending on degree of presence inthe soil. The permanent elements of the soil fauna, sometimes referred to as 'geobionts' develop through the whole of their life cycle in the soil and include the protozoans, nematodes, annelids, myriapods, isopods, mites, various insects including the Collembola, together with some molluscs. The figure following illustrates the basic differences between these various divisions.



Adapted from Wallwork (1970).

The body size of soil animals varies extensively. In general, modern workers classify these groups into three broad categories.

1. The micro-fauna. These animals are, in general, less than one millimetre in total length.

2. The meso-fauna, ranging from one millimetre to one centimetre in length.

3. The macro-fauna, in which the body size is greater than one centimetre in length.

In the present study the meso-fauna and the macro-fauna are given greatest emphasis. The limits of the various categories are rather arbitrarily defined. Modification of this basic arrangement has been proposed from time to time. Some authors prefer to use the term 'meiofauna' instead of meso-fauna (Murphy, P. & Doncaster, C. 1957).

The soil provides a variety of micro-habitats and it is not surprising that several different classifications based on habitat preferences have been devised. A distinction can be made, for example, between the aquatic fauna living in water-filled spaces and surface films covering soil particles and the terrestrial element. To the former grouping belong the protozoas, ratifers, tardigrades, copepoda, crustaceans and certain nematodes, while the bulk of the meso-fauna and macro-fauna belong to the latter.

With regard to locomotion, distinction can be made between burrowing animals and those which move through the soil by making use of existing pore spaces, cavities or channels. The distribution of burrowing species is largely independent of the cavity structure of the soil and there is little relationship between body size and depth distribution, although burrowing is obviously easier in loose as opposed to compacted soils. This grouping is considered to include many lumbricidae which eat their way through the soil, together with groups which may be considered more properly as 'excavators'. The non-burrowers are generally of small body size and can utilise existing soil spaces. Examples of this group are the micro-arthropods, mites, collembola, the soil water fauna, enchytraeids and symphylids. Larger animals such as the centipedes, isopods and certain lumbricids are morphologically adapted to squeeze through existing soil spaces and since this activity may enlarge pre-existing channels, these non-burrowers are difficult to distinguish from the burrowers.

A major activity of soil animals is feeding. In terms of this activity, the following groups can be defined :

1. Carnivores such as the carabid beetles, some staphylinid beetles, many mesostigmatid mites, the spiders, harvestmen and some molluscs.

2. Phytophages feeding on -
   (a) green plant material above the ground - e.g. molluscs and some lepidopteran larvae.
   (b) root systems - e.g. symphylids, larvae of some diptera, scarabaeids, coleoptera and molluscs.

3. Saprophages which feed on dead or decaying organic matter - e.g. the lumbricids, enchytraeids, isopods, millipedes, and some of the mites, collembola and some insects.

Many of the groups of soil animals considered above are not so restrictive in their feeding habits as to fit easily into one or other of the preceding classes. Species which will accept a range of food material, plant or animal, fresh or decaying, woody or herbaceous, are to be found particularly amongst the mites, collembola and the larvae of diptera and coleoptera. The diet of these miscellaneous feeders usually varies from place to place, time to time, season to season, depending on what is available in the way of food.

For more than one hundred years systematic investigation has been carried out in soil biology, that is, the interrelationships of plants and animals with the soil. Much data has been collected showing that soil invertebrates are an important factor in soil formation and soil fertility. In most cases investigations have been related to specific agricultural problems, for example, in New Zealand grassgrub and porina control; manurial trials and productivity. But little work appears to have been done, perhaps minimal work as a basis for investigation of conditions which occur with minimal interference by man.

It is known by the average farmer that a good sward of pasture will become rank and full of plants undesirable as fodder if left ungrazed and unmanured. At what rate does the reversion occur? Is there a natural cycle of change which will occur? What are the relationships between environmental factors?

STATEMENT OF HYPOTHESIS

It is the author's hypothesis that although seasonal and long-term changes occur in the pasture biota, the dominant factor in determining the structure of a pasture community is the condition of the soil-vegetation interface. In order to examine this hypothesis, records have been made of the changes that have occurred in flora and fauna, the effects upon biota of micro- and macro-climate as the pasture changes to rank, coarse weeds, and the qualitative and quantitative effects of an undisturbed sequence upon the biota of an enclosed pasture area.

SUMMARY : INTRODUCTION

The soil, in a similar way to all ecosystems, cannot be separated from the rest of the environment.

The inhabitants of the soil may be transient members of the soil ecosystem with little apparent direct effect on other biota, temporary members with a greater effect, or permanently living within the soil.

The effects of one group upon another are relatively unknown in New Zealand except for some groups of economic significance where the emphasis has been upon methods of control.

This research has investigated over a period of seven years, the inter-relationships of the biota; the effects of floral competition; the ways in which soil structure and chemistry affect fluctuating numbers of biota; and the role of plants in modifying the soil/air interface.

The author's emphasis has not been upon strict identification and nomenclature as such, but on the changes of groups of biota in relation to environmental factors, both annual and over a longer period of time.

These basic investigations can lead to further work in New Zealand with more direct attention being given to specific soil biota.

SECTION 2 : THE SITE

The main sampling site (known after this as the Hillcrest site) is situated at the north end of the campus of the University of Waikato. Until July, 1963 the area was used as an experimental farm unit in association with dairy research at the Ruakura Agricultural Research Centre. In July of 1963 the whole of the farm area was taken over by the South Auckland Education Board for development as the campus of the Hamilton Teachers College and the University of Waikato. With playing ground development, the area in which the sampling site is situated was stripped bare of top soil exposing the sub-soil. This top soil was piled for composting and later spread back across the area. A light sowing of the seed of pasture grasses was made in most areas, but as far as records can be ascertained, no sowing was done deliberately in the research area. This and several other areas were allowed to revert to natural pasture. No topdressing or fertiliser of any kind was applied after July, 1963. The area surrounding the site and the site itself are more or less flat with a very slight slope towards the north along the adjacent highway. The area is protected by a hedge 50 m to the north.

The sampling site measures 10 m by 10 m and is situated beneath a power pylon with the south leg of the pylon in the centre of the plot. A buffer zone of 1 m wide extends around the perimeter of the plot.

Two similar areas (i.e. similar in soil type, vegetation form, animal type and distribution) were utilised once the main survey of the Hillcrest area got under way. The purpose was to have parallel sampling plots for comparison. The Tamahere plot is located 7 km to the south-east of the Hillcrest plot, the Newstead area 5 km to the north-east of the Hillcrest plot.

References: Map NZMS1 N65 Hamilton
Hillcrest 825477
Tamahere 861419
Newstead 844483

The systematic description of the Hillcrest area is as follows: Horotiu sandy loam type of the Horotiu soil set; classified as a yellow-brown loam from alluvium. Parent material is described as a volcanic ash alluvium over well sorted rhyolitic sands and gravels.

Profile description is determined by the author using as a guide Kear (1959), Oyama (1967), and Taylor (1962).

Horizon

A1.1 — 0 - 6.4 cm, very dark greyish brown (10YR 3/2) fine sandy loam, very friable, strongly developed fine granular and crumb structure, matted with roots, boundary indistinct.

A1.2 — 6.4 - 15.2 cm, very dark brown (10YR 2/2) sandy silt loam, very friable, strongly developed medium and fine granular with crumb, many fine clean quartz grains, abundant fine roots, boundary irregular and indistinct.

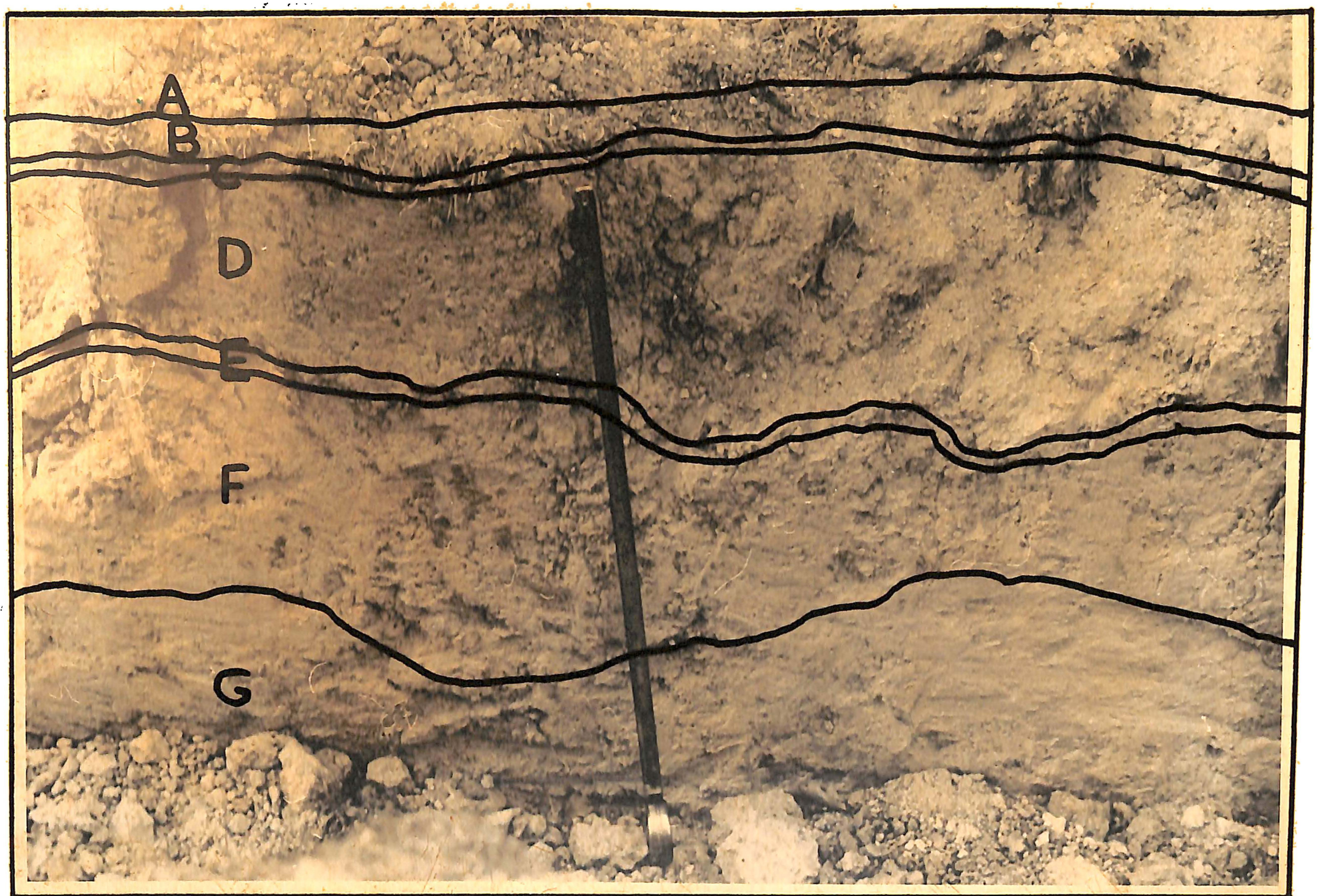
A-B — 15.2 - 22.0 cm, very dark greyish brown (10YR 3/2) and brown (7.5 YR 4/4) sandy loam, very friable, greasy, strongly developed coarse to medium granular breaking

	to fine granular and crumb, many fine roots, boundary indistinct.
B2.1	22.0 - 43.0 cm, strong brown (7.5 YR 5/6) sandy loam, very friable, greasy, moderately developed medium nutty, breaking to fine crumb, very fine roots, boundary diffuse.
B2.2	43.0 - 53.5 cm, strong brown (7.5 YR 5/6) coarse sandy loam, very friable, moderately developed coarse nutty, breaking to fine crumb and single grains, very fine roots, boundary indistinct.
Dr1	53.5 - 74.0 cm, strong brown (7.5 YR 5/6) coarse sand, loose single grained, few fine roots, boundary indistinct.
Dr2 & below	Yellowish brown (10 YR 5/8) coarse gravelly sand, loose.

In essence, the Tamahere and Newstead areas followed the general soil profile, although the Newstead area had a higher content of fine sand particles in the upper layers and the Tamahere area had coarser material, almost to gravel size, towards the base. However, in each case, the two parallel sampling areas had not been grazed, manured, trampled by livestock, or cultivated over the last ten to fifteen years.

(Personal communication - Mathieson, J.G. (1969), South Auckland Education Board.)

SOIL PROFILE - HILLCREST



KEY TO THE SOIL PROFILE - HILLCREST

A Actively growing vegetation.

B Litter layer - consisting of dead or dying plant fragments, not consolidated. Depth 0.5 - 10 cm.

C Humic layer - 3 cm. Very dark greyish brown, strongly developed crumb structure, matted with roots, high organic content, upper boundary indistinct.

D Disturbed layer - 15.0 cm. This represents the admixture of the original surface layers which were disturbed during 1964. Basically a dark brown sandy silt loam mixed with mostly decomposed organic material and fine rootlets from upper layers.

E Fine ash layer - 2.5 cm, fine textured, greyish white.

F Silt loam - 20 cm, strong brown, very friable, moderately coarse nutty texture breaking to fine crumb and single grains, organic matter limited to a few fine roots, lower boundary indistinct.

G Yellow brown coarse gravelly sand with some large pieces of pumice present (up to 5 cm), no organic material. This layer continues to at least 3 m below the present soil surface.

SUMMARY : THE SITE

The main site used for investigation, situated at Hillcrest, was enclosed in 1966 and allowed to revert from short grass pasture to a "natural state".

Two paralleled sampling sites were established at Newstead and Tamahere.

No fertilisers were applied to any of the areas, but Newstead and Tamahere were regularly mowed throughout the period of research.

Meteorological conditions were closely similar at all sites.

Soil type was of an alluvial sandy loam with indistinct boundaries between the upper horizons. The Newstead site had a greater percentage of fine sand in the upper layers than Hillcrest, and Tamahere had more gravel in the basal horizon.

At the initial establishment time when the sites were first investigated, the biotic complexes were similar.

SECTION 3 : MATERIALS AND METHODS

(a) Introduction and Sampling

It should be noted that the metric system of measurement is used in the test. Measurements in the field were made using the English system. In the test, 2.54 cm is equivalent to 1".

As a guide to sampling methods and techniques the following authors were consulted: Bourdeau (1953); Brown (1954); Cottam (1956); Evans (1955); Kershaw (1970) and Odum (1964).

An initial survey of the Hillcrest site in September, 1966 indicated that 25 samples would give 85% reliability of sampling and 68% predictability of the mean for expectation of the numbers of each species of the fauna at any sampling time.

As mentioned in Section 2 : The Site, the Hillcrest site measured 10 m by 10 m. This was sub-divided with permanent markers of plastic-coated wire into units of 2 m by 2 m. Each 4 m^2 unit would then be sub-divided into smaller units through the use of a portable hand frame measuring 1 m by 1 m and sub-divided into 25 smaller units. Through the use of sub-gridding, a grand total of 2,500 potential samples could be taken in the 10 x 10 m site.

Once each four-week period, 25 random samples were taken from the site. The positions for these samples were selected from a table of random numbers and each sampling position recorded on a chart to prevent repetition. Each sample measured 10.16 cm diameter and was taken to a depth of 15.24 cm. This size of sample was selected so that comparisons could be made with data obtained by Salt, Hollick, Raw and Brian (1948). Each sample was placed in a polythene bag, labelled, numbered and sealed. Details of the stainless steel plug cutter can be seen in Figure 1. The samples were kept at room temperature away from bright light and with the soil-vegetation interface uppermost, returned to the laboratory and extracted within forty-eight hours. It should be noted at this point that all samples were taken between 10.00 a.m. and 2.00 p.m.

A full floral survey was carried out, also at four-weekly intervals, but in the intermediate periods between sampling for soil plugs. This procedure minimised interference with the site. The survey consisted of marking in the position, both of individual plants where these were tall or isolated from similar plants, and the perimeters of clumps of plants where individuals could not be differentiated. Recording was made from two fixed datum points, on the north and south sides of the site.

From the beginning of 1967 until the end of 1971, systematic temperature records were made three times a day, that is, between 7.00 and 8.00 a.m., 12.00 noon and 1.00 p.m., 5.00 and 6.00 p.m. Temperature records in degrees Celsius were made at + 61.0 cm, at the soil-vegetation interface, -16.5 cm, and -30.0 cm, with a mercury in glass thermometer in $\frac{1}{10}$ steps. Relative humidity was recorded with a recording hair hygrometer. The daily rainfall was recorded between 7.00 and 8.00 a.m. In 1971 and 1972 all temperatures were recorded with the aid of a Grant mini-recorder moving chart with four thermistor probes. The probes were placed in the positions mentioned for the previous thermometers.

(b) <u>Extraction</u>

Initially, all samples were hand extracted within 48 hours of collection. Simply, this involved subjecting the fauna of each sample to the effects of heat and uni-directional light. A glass-topped table, with a 100 watt lamp below an open glass panel and a 100 watt frosted lamp shining from the left, was used to drive the animals from the soil. Each plug of soil had the vegetation clipped from the top, and was broken into smaller fragments, ultimately to be sorted through piece by piece, moving both active and inactive stages from the soil. With the drying effect of the heated panel below the table and the light above the table, most mobile animals moved very rapidly to where they could be captured, separated and preserved for identification. The sample was sorted again under a swinging arm binocular microscope, looking for inactive forms, such as cocoons, cysts, and non-mobile larvae. (For details of sorting table, see Figure 3.)

Hand sorting was approximately 95% accurate, of course improving with practice and skill of the author. During spring, summer and autumn, hand sorting was reasonably effective, but difficulties were experienced with the greater water-logging of the soils during winter months. Because of this difficulty, a modification of a split funnel extractor was developed, being an adaptation of the Haarløv system.

Choice and design of author's extractor

When one is extracting for animals of one particular type, or one particular size range, there are few difficulties encountered. But considerable difficulties arise when 20 or more different groups are being extracted at the same time. These groups may range in size from 1 mm or smaller, to 9 cm or bigger. Most methods are based upon producing a gradient of soil conditions which drive fauna away from unfavourable (artificial) towards favourable (normal) conditions. Repellent stimuli include heat, light, desiccation and chemicals. However, no one extraction method is absolutely effective where a wide variety of fauna is to be extracted. (MacFadyen (1955) in Kevan, Soil Zoology, Butterworths, pp.36-40.)

In the Berlese funnel (Berlese, 1905) the main objective was to dry out the samples. Since the heating was from a water jacket below the sample, it could not have been Berlese's intention to achieve any directional response to heat, but in a dry room it is probable that at least in the initial stages of desiccation the air in the funnel would have been wetter than that of the room.

Tullgren (1918) introduced a more convenient method of heating by means of an electric lamp. Because the heat and desiccation are more severe in the upper layers of the samples than the lower, there would result in a tendency for animals to be driven downwards. A large number of modifications of the Tullgren funnel have been used all over the world since then (Wood, 1965).

Haarløv (1947) drew attention to the ill-effects of condensation of water within the funnel, due to the fact that during the extraction process the animals emerge from the soil in two main batches, the first corresponding to the establishment of high temperature in the funnel, and the second at the completion of the drying out of the soil. MacFadyen (1953) examined the critical angle of the funnel within the Haarløv extractor, concluding that if the angle were greater than 45°, few condensation difficulties would occur.

With these modifications taken into account, the author designed a battery of Berlese/Tullgren/Haarløv funnels incorporating certain modifications of his own. (For details of extractors, see Figure 4.) In an investigation of vertical distribution of biota, the modified split funnel was extensively used. (See details of extraction in Section 7.)

Salt, Hollick, Raw and Brian (1948) used a magnesium sulphate flotation solution of specific gravity 1.2, followed by benzene inter-face separation. This was used principally for wireworm extraction but was reasonably effective with arthropods about 2 mm long and 0.2 mm broad. Modifications by Salt (1952) allowed extraction of other groups, but in each case the extraction was confined to organisms of a narrow sized range and the size of soil sample is limited to approximately 100 cc.

Wilcocks, C., Ruakura (personal communication 1970) has used a set of rotating wash sieves to extract the larvae of Altermetaponia rubriceps. In a comparison of Wilcocks' methods and those of the author (see page 26), the author's extractors removed similar percentages of fauna but less damage occurred than in the wash method.

Scott (1966) used extractors designed by Kempson, Lloyd and Ghelardi (1963) which maintained a high humidity at the extractor base. Extraction took a total of 14 days for each sample. It was considered by Scott that some matching out of biota could have occurred during the extraction time, in some cases elevating the numbers of organisms in some groups above the actual number occurring at the sampling time.

With the quantity of material required to be extracted by the author, Scott's method was not used. It was also found by the author that 90% of all microbiota was extracted within 24 hours. This was in accord with Scott's findings. Also, the more rapid extraction by the author's method lowered the chances of population increase through hatching. For these reasons, the author preferred the use of a modified split funnel extractor to that of other methods.

(c) Preservation

In general, biota extracted were preserved in 70% methanol with glycerol added. Acarina and collembola were preserved in Ble's solution and mounted for examination in Faure's medium. Dipteran and lepidopteran larvae and pupae were preserved in Oudemann's fluid. (For details of these solutions, see Appendix 2.)

(d) Counting and identification

Macro-fauna presented no difficulty in counting, but meso-fauna ranging down to 1 mm in total length was counted by placing the collecting dish on a grid measured in millimetre squares. The container with preservative and meso-fauna was examined under a swinging-arm binocular microscope (X20) with full illumination. A photographic record was made of each particular form of animal and spirit collections were maintained as a permanent record. Where the author was uncertain of identification, specific groups were sent to specialists in the field.

(e) Chemical and Physical Properties of the Soil in Each Plot

At each of the three sites, soil cores were taken. Each core measured 10.16 cm diameter and 91.5 cm depth. Each core was encased in polythene, sealed and taken to the laboratory. In the laboratory each core was divided into sections, that is, 0 - 30.4 cm, 30.4 - 61.0 cm, and 61.0 - 91.5 cm. Surface vegetation was removed and five random samples taken from each core section. Each random sample was weighed, oven-dried for 24 hours at 100° Celsius and weighed to constant weight on a Metler balance. Each random sample was then put through a sieve series. Sieve sizes: 4 meshes per cm^2, 16 meshes per cm^2, and 100 meshes per cm^2. In this way, percentage moisture, percentage gravel, coarse sand, fine sand, silt and clay could be calculated; the means of each 5 random samples being taken as equivalent to the figures for each section of the core. (For details of the physical properties of the soils of each area, see Table 2.)

Gravel is here defined as those particles bigger than 2.5 cm cross-section;
coarse sand 2.5 - 0.2 cm;
fine sand 0.2 - 0.01 cm;
silt and clay less than 0.01 cm cross-section.

Chemical analyses made were carbon percentage and nitrogen percentage. Using the method of Metson (1956) to calculate nitrogen percentage, 50 g random samples (five 10 g samples from each section of each core) were taken from dried material and tested with a standard Lovibond comparator. Similarly, carbon percentage was determined by taking 50 g samples of dried material, heating to destruction, cooling, weighing and calculating the percentage loss of carbon through ignition. (See Appendix 3 for details of soil nitrate determination.)

(f) Precipitation

A standard 12.5 cm diameter collecting funnel was set up in the Hillcrest site. A thin layer of paraffin oil was placed in the collecting vessel to prevent evaporation. Each day, between 7.00 and 8.00 a.m. the precipitation was collected, measured and recorded.

(g) Moisture Content of the Soil

Every four weeks, as samples were collected, separate surface and sub-surface samples were taken to measure soil moisture content. In each case, five of these samples were taken, each sample weighing 50 g. Each was weighed, oven-dried for 24 hours to 100° Celsius, weighed to constant weight and moisture content calculated.

(h) Soil pH

In a similar manner to the obtaining of sub-samples for moisture content of the soil, soil pH was calculated. 10 g of oven-dried soil were taken, shaken with 50 cc of distilled water, held for 24 hours in a sealed container, then measured, using the electrodes of a standard electric pH meter. Similar methods have been used by Chapman et al (1940); Pearsall (1952).

(i) Atmospheric and Soil Temperatures

Until an electronic temperature recorder became available in 1971, all temperatures were taken with freely-suspended Celsius thermometers. Atmospheric temperature was recorded in the shade 61.0 cm above ground level, as suggested by Redway (1931). At each soil recording position, a mercury in glass thermometer graded in tenths of a Celsius degree was placed. Each thermometer was placed in position encased in a perforated copper tube close-fitting to the soil and to the thermometer, but leaving the mercury bulb touching the substrate. This method of recording soil temperatures was suggested by Connell (1923). One criticism of this method would be that some transfer of heat could occur through the tubing, but as can be seen from Table 1, comparisons made between the freely-suspended thermometers and the Grant Electronic Temperature Recorder show very small difference between maxima and minima with the two methods of recording. Recording of freely-suspended thermometers was made three times during the day, that is, between 7.00 and 8.00 a.m., 12 noon and 1.00 p.m., 5.00 and 6.00 p.m. The Grant thermometer recorded at one hourly intervals.

(j) Soil Particle Size

From each sample, 100 g of soil were taken at random throughout the core length and oven-dried for 24 hours at 100° Celsius. 50 g of each dried sample were taken, graded through 10 cm diameter soil sieves of mesh size $4M/cm^2$, $16M/cm^2$, and $100M/cm^2$, and the fractions of each sample weighed and recorded.

In a second set of samples from each core, soil was taken at 1 cm depth intervals and graded for particle size using the same method. These methods were suggested by and modified from Boswell (1935) and Kilmer (1949).

(k) Analysis of the Botanical Composition

From January 1967 until December 1971 at 4-weekly intervals, the flora of the Hillcrest site was sampled. The standard datum points on the north and south sides of the site were used for plotting in the positions of tall plants, that is, over 1 m in height, single or isolated plants and the perimeters of vegetation clumps.

Photographs were taken of the area from each of the datum points on 35 mm Kodachrome transparencies.

Taking 10 random positions within the site, the depth of litter was recorded, the average height of the vegetation and the height of the greatest clumps. In addition, a record was made of those plants in flower. The resulting survey sheets were plotted for change in phenology of flowering of plants, mean height of vegetation, greatest height of clumps and depth of litter. Subsequently, the total area covered by each of the species present was plotted using a Koizumi Compensating Planimeter type KP-27 and expressed as percentage of site cover for each species.

COMPARISON OF METHODS FOR EXTRACTING SOIL BIOTA

Thirty random samples were taken in February 1970 from an area adjacent to the Hillcrest site and sorted using the three methods. Ten samples were extracted each way. The assumption made is that each sample contained the same proportionate numbers of each faunal group.

	Rotating sieves	Split funnel	Handsorting
Nematoda	12 = but ϕ	13 +	12
Lumbricidae	7 = but ϕ	7 +	7
Lumbricid cocoons	10 +	5 - and ϕ	9
Enchytraeidae	3 - and ϕ	14 +	12
Mollusca	2 - and ϕ	2 - and ϕ	4
Acarina	8 - and ϕ	12 +	9
Myriapoda	2 - and ϕ	3 =	3
Isopoda	0.5 - and ϕ	7 +	5
Altermetaponia all stages	84 +	67 + but ϕ	62
Other groups	16 - and ϕ	18 +	17

Figures given are means for ten samples.

ϕ indicates some specimens damaged.

\+ indicates greater efficiency than handsorting.

\- indicates less efficiency than handsorting.

= indicates equally efficient to handsorting.

SUMMARY : MATERIALS AND METHODS

Regular sampling of the Hillcrest site occurred at 4-weekly intervals over a 7-year period. Similarly, samples were taken during 1970 and 1971 at Newstead and less frequently during this period at Tamahere.

25 samples were taken each time. The samples measured 10.16 cm diameter and 15.24 cm depth.

Quantitative analysis was made of the number of each group of animals present, the fluctuation in seasonal numbers and the variation in their depth in the soil.

Initially, the faunal extraction was by hand but a modified split funnel extractor was later developed by the author.

Soil analyses were made for particle size, pH, carbon and nitrate concentration, and moisture content.

Thrice-daily temperature records were made : 61.0 cm above ground level, at the soil/vegetation interface and 16.5 cm below soil level. Precipitation was recorded daily.

The positions of plants were plotted at the Hillcrest site, and changes in flowering and vegetation fronts recorded.

A photographic record was made of vegetation and selected fauna.

SECTION 4 : ENVIRONMENTAL FACTORS

(a) Introduction

Probably the most important environmental factor affecting the life of animals in the soil are soil moisture and soil temperature. Not only are there far-reaching differences between water-logged soils, and soils which are at least temporarily dry, but there are also considerable differences according to the degree to which the soil humidity fluctuates annually.

The responses of different burrowing animals to moisture conditions are rather different. The earthworms(Lumbricidae), for example, need at least some liquid soil water for their existence, while other animals of a somewhat similar type are content with saturated air, for example, the grubs of scarabids and many other insect larvae. The majority of full grown insects, however, can withstand the desiccating effects of a completely dry atmosphere for at least a short time, although many of them scarcely ever expose themselves voluntarily to such conditions. In this connection, it is interesting to note that mites which burrow in the soil are often found in greatest numbers just after sundown when the air is saturated close to the ground. (Tarras-Wahlberg, 1961.)

An excess of soil moisture is harmful to certain forms: the ordinary terrestrial earthworms are killed by floods and leave their tunnels when these are inundated. However, Schaerffenberg (1942) showed that the larvae of elaterid beetles have proved to be decreasingly flood-resistant with rising temperatures, which means that they are considerably less able to withstand flooding during summer than during spring inundations. Experiments carried out

(Madge, 1964 (a), 1964 (b); Hayes, 1966), have demonstrated specific differences in the response to survival in a graded series of relative humidities, and Scott (1966) has shown differences of survival times in relation to humidity in litter-dwelling isopods. Information of this kind is difficult to relate to natural behaviour and distribution patterns, for no really accurate method has yet been devised to measure the relative humidity of the soil atmosphere. It has been shown by Edelfson (1943), Marshall (1959) that if the moisture content of the soil remains above the hygroscopic co-efficient (i.e. when soil moisture no longer clings to the outside of soil particles but remains free in the spaces), soil atmosphere is to all intents and purposes saturated. However, the hygroscopic co-efficient may not be a good measure of the desiccating effects on biota, and it may be more realistic to describe moisture responses in terms of saturation deficit (i.e. how far below the soil saturation point the moisture content has dropped). This is an area of soil biology which needs much more attention, particularly the reaction of micro-arthropods to the variations of soil moisture. (Vannier, 1970.)

The amplitude of the temperature wave in the upper layers of the soil is related to the amount of solar radiation falling on the soil surface. How much of this radiation is intercepted by the surface vegetation before it reaches the ground would depend to a large extent on the angle at which the sun's rays strike the vegetation. (Burns, 1923.) This may be governed, in turn, to topographical features of the locality, e.g. the height of vegetation and the depth of litter cover.

The heat wave propagated by radiation striking the soil surface is considerably dampened in the lower layers, particularly in highly organic soils. As a consequence, there is a time lag between temperature changes at the surface and those in the lower layers. Often, there is a clear correspondence between changes in air temperature and changes in litter temperature, although the latter have a lower amplitude than the former. (Note Graphs 1a, b; 2a, b.) Temperature changes in the deeper humus and mineral particle layers are out of phase with those of the air and litter. These deeper layers are still in the process of cooling during the morning period when air and litter temperatures are rising. During late afternoon when air and litter temperatures drop, the lag effect is such that those of the humus and mineral particles of the soil continue to rise although less sharply as the night approaches. Some authors (Ashraf, 1970; Mail, 1930; Millar, 1954) have noted that temperatures in lower depths of the mineral particle layer do not fluctuate appreciably during the diurnal cycle.

Clearly, the soil micro-climate offers temperature conditions which show less daily variation than those in the air above, and which decrease progressively in amplitude with increasing depth in the soil. It is known that soil animals, such as the cryptostigmatid mites, show a preference for certain temperature conditions (Wallwork, 1960; Madge, 1961) and that they undergo regular vertical movement during their 24 hour cycle (Tarras-Wahlberg, 1961; Wallwork & Rodriguez, 1961). Such changes in the vertical distribution pattern may be related to temperature preferenda, at least in part, and may represent a device by which the fauna is able to remain in equable temperature conditions despite diurnal variations in the temperature profile. (Note Graphs 1c, 2c - Hillcrest and Newstead.)

A similar situation can be described for seasonal fluctuations.

(b) Botanical Composition of the Pasture

In August 1966 when a preliminary survey was made of the Hillcrest plot, the area had recovered from the 1963 removal of top soil, composting and subsequent redistribution, to produce a short, sparse pasture. The dominant plants at this time were browntop, Agrostis tenuis (Sibth.) and white clover, Trifolium repens (L.). Scattered throughout the plot were soft annuals and rosette plants, namely, chickweed, Cerastium glomeratum (Thuill.); pennyroyal, Mentha pulegium (L.); dandelion, Taraxacum officinale (Weber.); cat's ear, Hypochaeris radicata (L.) and broad-leaved plantain, Plantago major (L.).

With the growth of pasture in the enclosed site at Hillcrest, many of the small soft annuals, rosette plants and low-growing perennials became crowded out. By August 1972 the pasture had changed completely. The dominant forms were: Yorkshire fog, Holcus lanatus (L.); browntop, Agrostis tenuis (Sibth.), and prairie grass, Bromus unioloides (Beauv.). Creeping buttercup, Ranunculus sardous (Crantz.) was co-dominant with Yorkshire fog when present, but was suppressed where Yorkshire fog was absent. (For details of botanical composition and percentage changes over the study period see Tables 11, 12.) The depth of litter, mean height of tallest plants, and mean height of vegetation varied from season to season and over the length of the study period. (For details of this change see Table 13.)

(c) Soil Particle Size

To a great extent, the depth to which any organism can penetrate into the soil will depend upon (a) the size of the organism - hence its mechanical ability to penetrate, and (b) the particle size of materials in a soil layer.

At each of the three sites, up to 85% of all organisms are found within the top 3 cm of soil, where organic materials are at a maximum, allowing many pore spaces for easy penetration. The greater the depth in the soil the closer together become the soil particles, so that penetration to depth can be achieved only by smaller organisms or larger, mechanically strong organisms, such as some annelids which can push between the close-packed particles.

Dhillon and Gibson (1962) have shown that in the non-burrowing Collembola a loamy grassland soil, a close correlation exists between body size and soil porosity - larger forms being confined almost entirely to the upper layers.

(d) Precipitation and Soil Moisture Content

Seelye (1946) made an analysis of precipitation in the Waikato Valley and concluded for Ruakura (34 years of records), just 2 km from the Hillcrest site, that the following conclusions could apply :

1. Precipitation is spread evenly throughout the year with the winter maximum beginning in April and the summer minimum beginning in November.
2. The ratio of winter to summer precipitation is 1.5 : 1.
3. Mean precipitation is 1100 - 1200 mm per year with a variability of 12%.
4. Days with rain average 160 days per year.
5. During any year, a soil moisture deficit exists in the top soil for 2 to 4 months. This can be expected 45% of summers.

The author's records for the Hillcrest site (1967-1972) although of a shorter duration than the Ruakura data, would confirm the conclusions Seelye has reached.

The precipitation at the Hillcrest, Newstead and Tamahere sites is very similar in quantity and annual distribution, but localised rain storms can cause loss in soil fauna, where surface water lies undrained for some time. The greatest rainfall recorded at Hillcrest occurred February 26-27, 1967 when 304 mm were recorded in 36 hours. Unfortunately, no fully implemented recording system was functioning at the other two sites, but local residents mentioned that the rain was "light". By contrast, January 1970 recorded just 38 mm of precipitation for the whole month at each of the three sites.

If comparison is made between the Hillcrest and Newstead sites (Graphs 1d and 2d), it would appear that in spite of great similarities of soil type, floral and faunal composition, the Newstead site with its poorly developed vegetation and litter cover maintains a lower soil moisture content during summer. This is the time when the greatest percentage of soil organisms are close to the soil-vegetation interface and moisture needs to remain above the critical survival level. At the Hillcrest site, by contrast, with its vegetation and litter cover well developed during the summer, the moisture content of the soil remains high and the organisms remain more evenly distributed throughout the top soil. Furthermore, the total numbers of organisms in each site show a close relationship to the percentage of soil moisture present. Many authors have recognised this factor, i.e. soil moisture content is a prime factor in the survival of small litter- and soil-inhabiting arthropods. (See Scott, 1966; Adams, 1971; Jacot, 1940; McMillan, 1969; Metz, 1971; Solomon, 1937.)

(e) Soil pH

The vast majority of pasture sub-soil invertebrates exist within a narrow range of pH levels. Ghilarov (1959) maintains that the fluctuations of numbers of soil invertebrates are largely unaffected by oscillations of pH levels, due to the impervious nature of exoskeletons. The author has not been able to substantiate or disprove this hypothesis, but from the data available, it would appear that fluctuations in annual population figures associate more closely with temperature and moisture fluctuations than with pH variation.

In general, the pH is more acid in the upper soil layers than in the lower soil (see Table 2, Soil Analysis). The three sites are similar in this respect.

Annual fluctuations (see Graph 3e, Table 4) show that the top 15 cm of soil at Hillcrest have a mean pH of 6.13 (range 5.59 - 6.58) during 1966-1971. The greatest acidity occurs during the winter period (June, July, August) as breakdown of organic material occurs, soluble nitrate increases and organic carbon decreases. The top soil is least acid during summer (December, January, February) as maximum vegetation growth slows down, soluble nitrate becomes unavailable to saprophagous organisms and accumulates as litter.

At Newstead, the greatest acidity is during winter as rapid release of nitrate occurs - although vegetation growth is minimal with low temperatures. This acidity is maintained over the spring and summer period when fresh, soft, rapidly-growing vegetation is removed by frequent mowing. Decomposition is rapid in this period and no litter layer builds up. (For Hillcrest/Newstead comparison see Graph 3f.)

No data is available for Tamahere.

Long-term change in pH would seem to be minimal. Parker, F. (1972 - personal communication) has stated that an area adjacent to the Hillcrest site had pre-1963 pH levels of 5.4 - 5.6. However, the exact sampling areas were not stated in the records of Ruakura Agricultural Research Centre. On the Hillcrest site, little change in pH has occurred during the period of sampling. The pH in 1966 was 6.13 and in 1972 the pH was 6.20; the mean for the period as stated before is 6.13. The author considers that under field conditions where fertilisers are not added to an area, the pH tends to remain relatively stable, apart from seasonal fluctuations, probably due to the buffering action of clay colloids. Franz (1953) substantiates the author's findings with his work on the breakdown of clay colloids by lime application and the consequent pH fluctuation.

(f) Atmospheric and Soil Temperatures

As stated in the introduction to this research, temperature near the ground is a critical factor in the development of the biota of a grassland area - the mean annual temperature, maxima and minima must all be considered.

To quote Wallwork (1970), "There is still much to be learned about the spatial and temporal variability in soil temperature conditions, and the effect of this variability on the distribution and activities of soil organisms. In general, moist soils show less temperature fluctuation than dry soils, for higher moisture content reduces the amplitude of the temperature change. In explosed grassland, the little vegetation cover present does not prevent the soil surface from receiving large amounts of direct solar radiation, and temperatures at the air/soil interface may be higher than those of the air above, during summer [author's note - see Graph 2a, b, Newstead]. The activity of the soil fauna may be related to these temperature characteristics."

When a comparison is made between Graphs 1 a, b, c, d, and Graphs 2 a, b, c, d, the following can be observed (pp.37-40) :

+61.0 cm

°C	MN	MX	MIN	RANGE
Hillcrest	15.0	31.5	-3.0	34.5
Newstead	15.3	31.0	-3.0	34.0

Interface

°C	MN	MX	MIN	RANGE
Hillcrest	14.4	26.0	-1.0	27.0
Newstead	14.7	28.0	-3.0	31.0

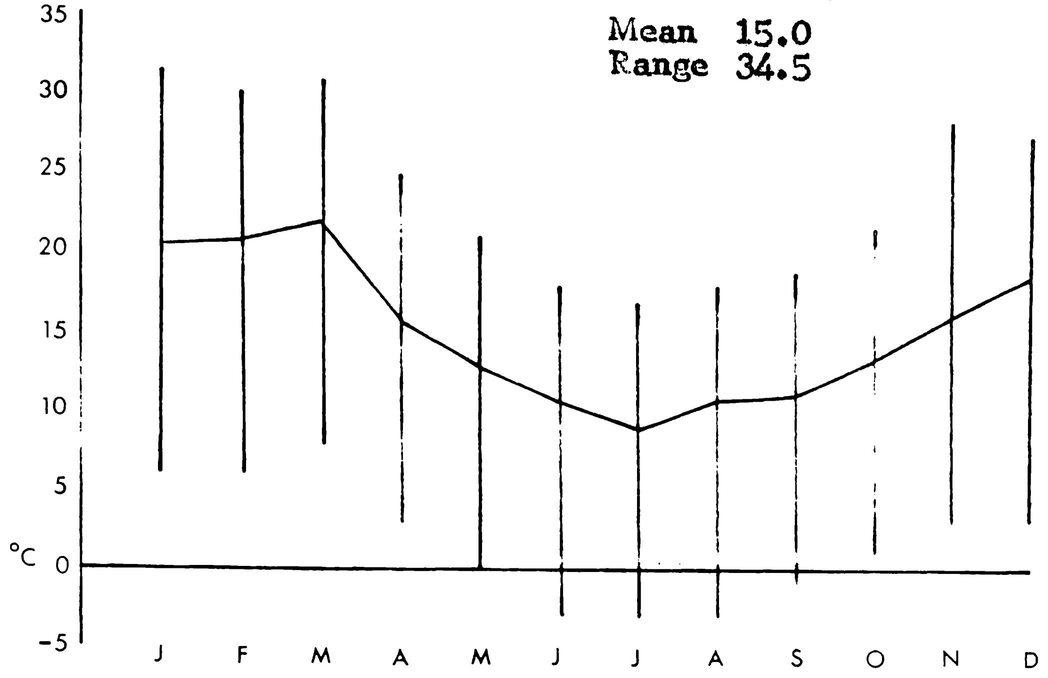
-16.5 cm

°C	MN	MX	MIN	RANGE
Hillcrest	11.2	23.0	5.0	18.0
Newstead	15.4	25.0	2.0	23.0

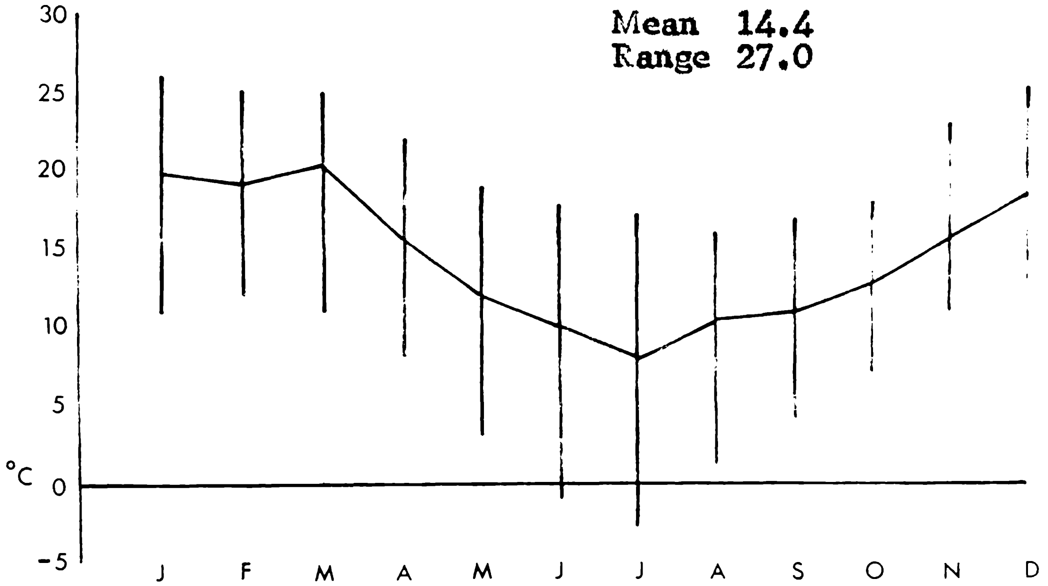
	Mean Soil Moisture %
Hillcrest	90.4
Newstead	87.1

1968-1971 ANNUAL TEMPERATURES - HILLCREST

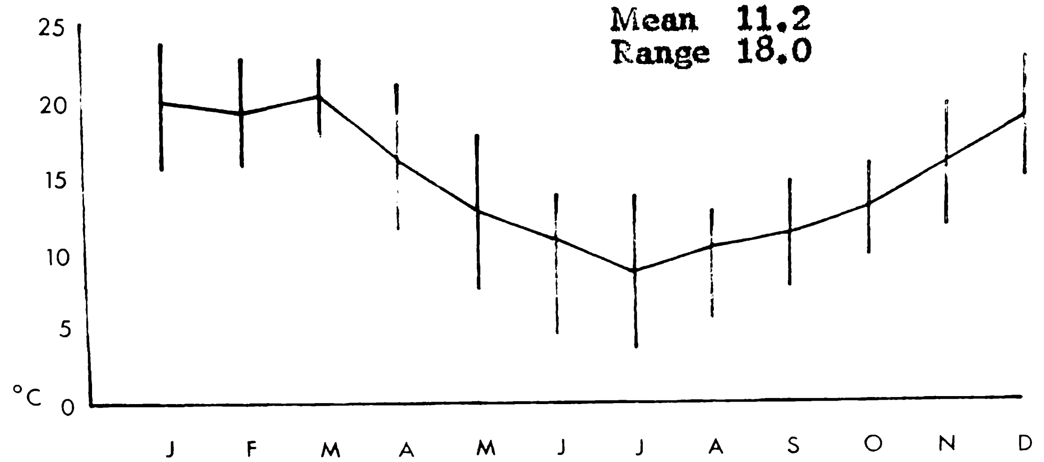
GRAPH 1a AIR TEMPERATURES + 61.0 cm



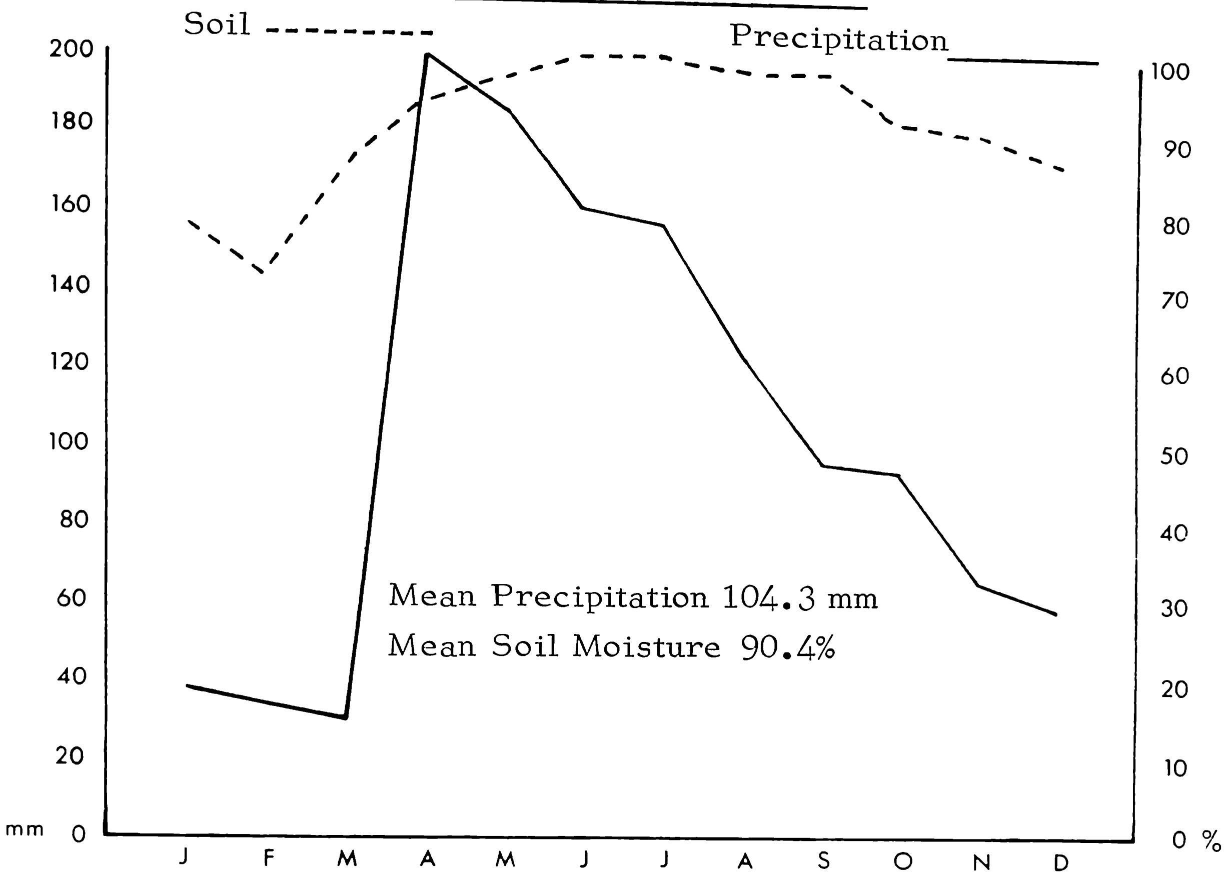
GRAPH 1b INTERFACE TEMPERATURES



GRAPH 1c SOIL TEMPERATURES -16.5 cm

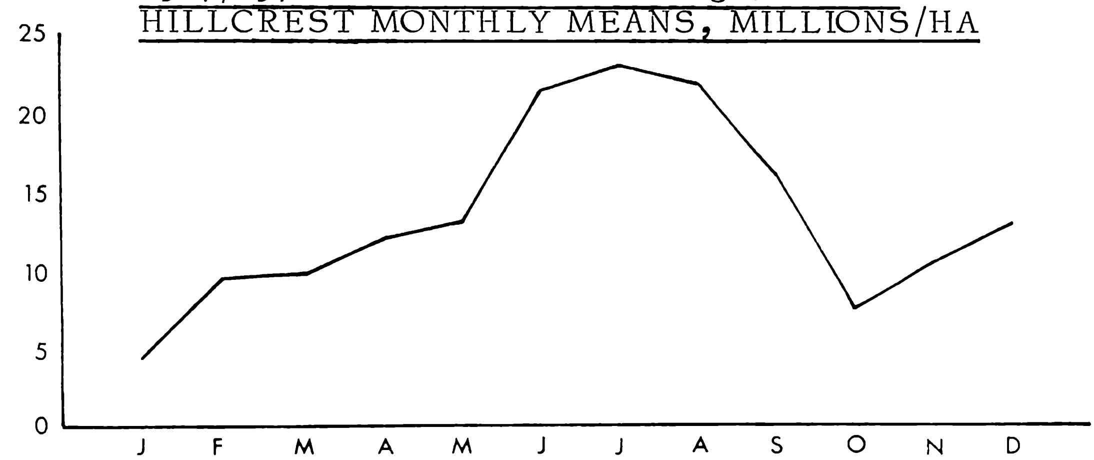


1968/1971 PRECIPITATION & SOIL MOISTURE
HILLCREST MONTHLY MEANS



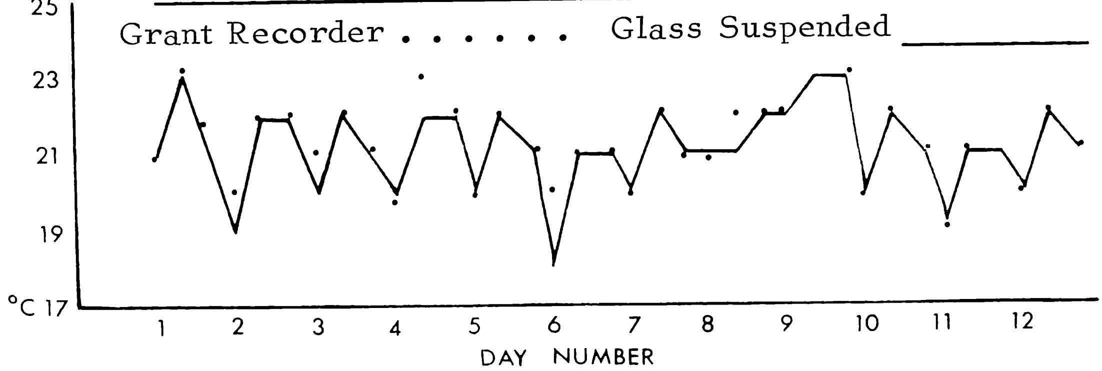
GRAPH 1e

1967/1971 TOTAL FAUNA TOP 15 CM SOIL -
HILLCREST MONTHLY MEANS, MILLIONS/HA



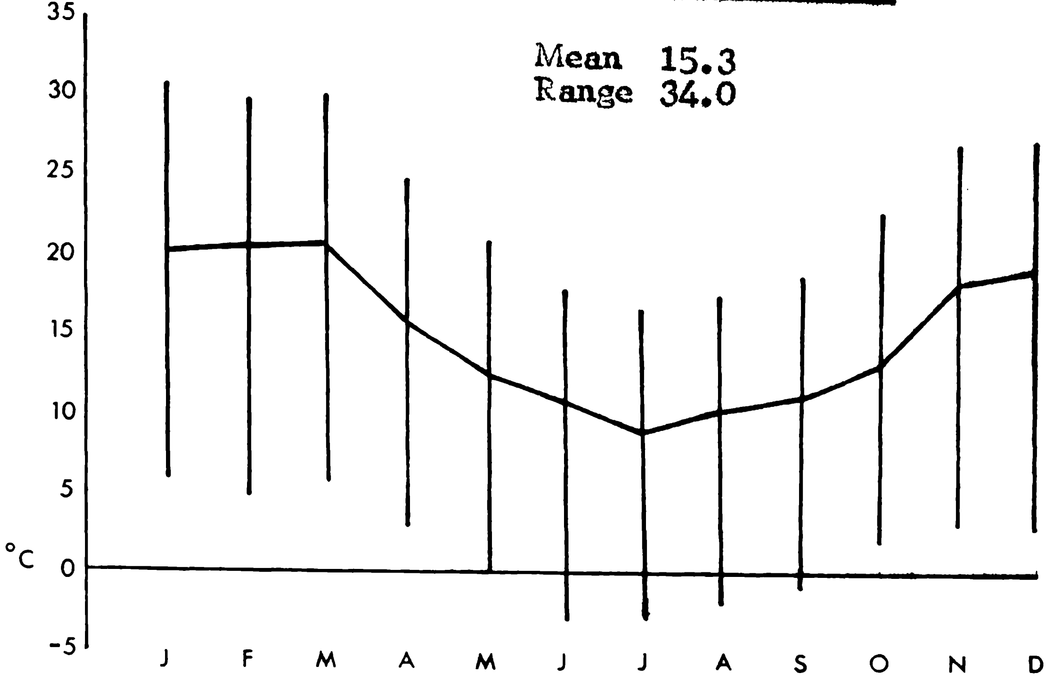
GRAPH 1f

SOIL TEMPERATURE - 15 CM, MARCH 1971
HILLCREST THERMOMETER COMPARISON

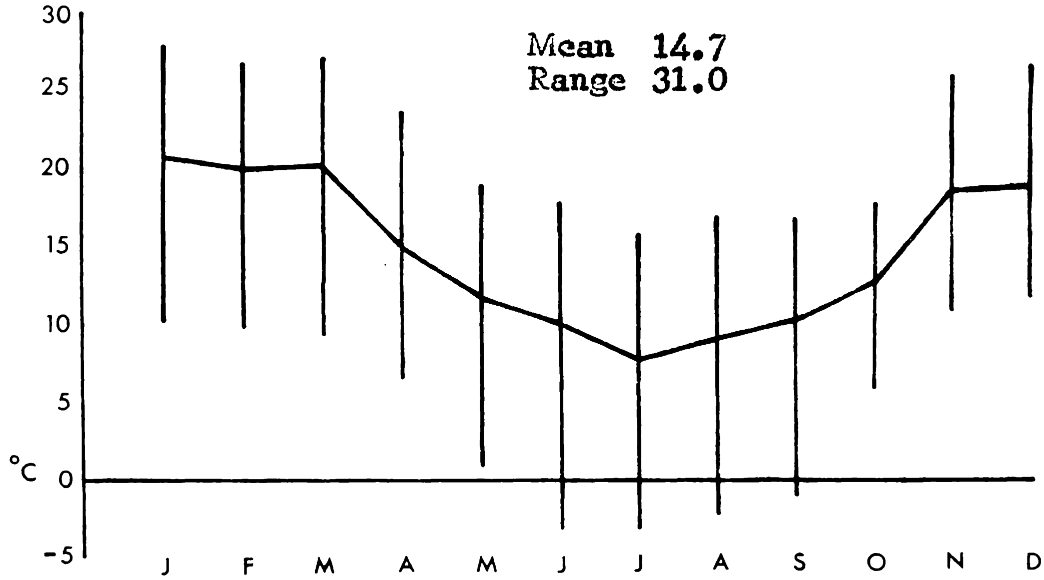


1970-71 ANNUAL TEMPERATURES - NEWSTEAD

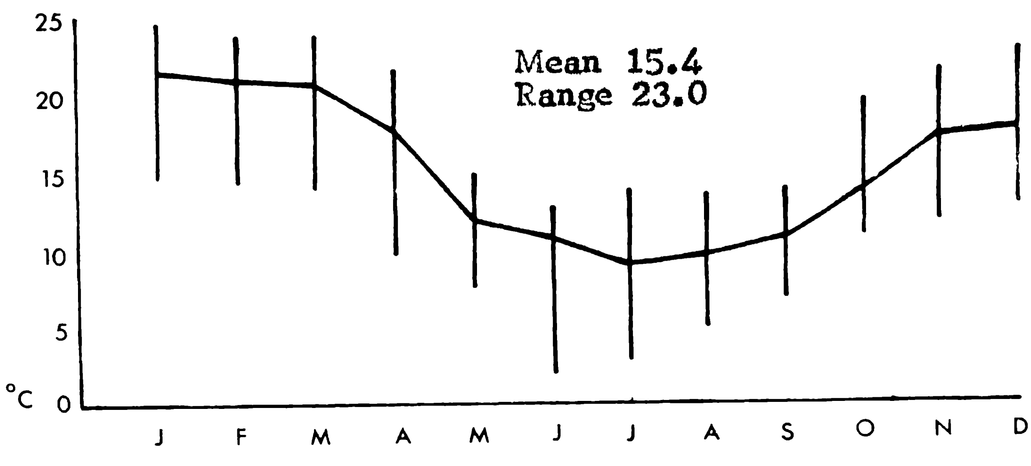
GRAPH 2a AIR TEMPERATURES + 61.0 cm.



GRAPH 2b INTERFACE TEMPERATURES

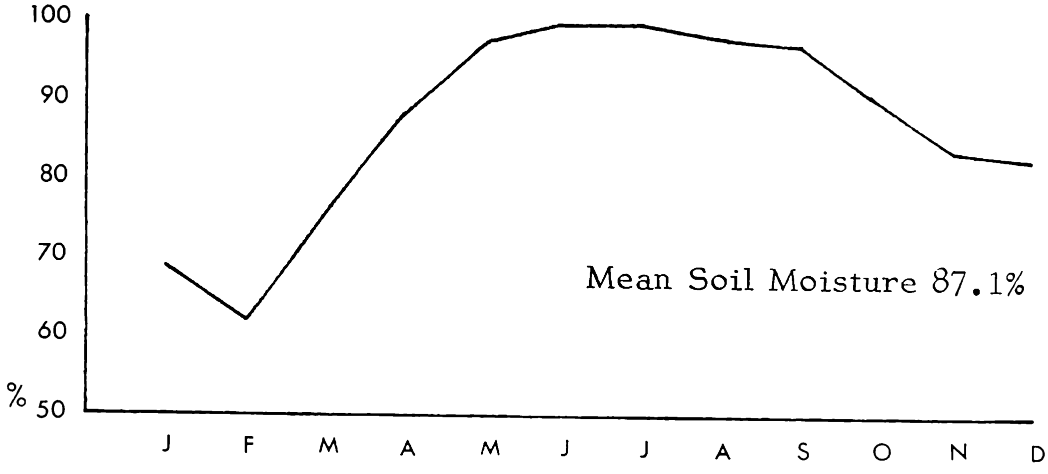


GRAPH 2c SOIL TEMPERATURES -16.5 cm.



GRAPH 2d

1970-71 SOIL MOISTURE - NEWSTEAD MONTHLY MEANS



METEOROLOGICAL DATA - NEWSTEAD, 1970-71

	AIR + 61.0 CM			INTERFACE			SOIL -16.5 CM			Moisture %
	MN	MX	MIN	MN	MX	MIN	MN	MX	MIN	
J	20.2	31.0	6.0	21.0	28.0	10.1	21.8	25.0	15.0	68.20
F	20.6	30.0	5.0	20.0	27.0	10.0	21.1	24.0	14.8	61.80
M	21.0	30.3	6.0	20.2	27.4	9.8	21.0	24.0	14.6	75.80
A	15.6	25.0	3.0	15.0	24.0	6.8	18.0	22.0	10.0	88.20
M	12.8	21.0	0.0	11.8	19.0	1.0	12.2	15.0	7.8	97.20
J	10.8	18.0	-3.0	10.2	18.0	-3.0	11.0	13.0	2.0	100.00
J	9.0	17.0	-3.0	8.0	16.0	-3.0	9.2	14.0	3.0	100.00
A	10.4	17.8	-2.0	9.4	17.0	-2.0	9.8	13.8	5.0	98.50
S	11.2	19.0	-1.0	10.2	17.0	-1.0	10.8	14.4	7.0	98.50
O	13.2	23.0	2.0	12.8	18.0	6.0	14.0	20.0	11.0	90.30
N	18.8	27.8	3.0	18.8	26.2	11.0	17.8	22.0	12.0	84.21
D	19.4	28.0	3.0	19.0	27.0	12.0	18.2	23.0	13.0	83.27
MN	15.3	23.9	1.6	14.7	22.1	5.1	15.4	19.2	9.6	87.12

TABLE 1

COMPARISON OF SOIL TEMPERATURE RECORDING METHODS - HILLCREST, MARCH, 1971 (PROBES AT -15.0 CENTIMETRES)

Day	Mercury in glass, suspended Thermometer °C	Grant Recorder Thermistors °C
1	21	21
	23	23
	22	22
2	19*	20
	22	22
	22	22
3	20*	21
	23	23
	21	21
4	20	20
	22*	23
	22	22
5	20	20
	22	22
	21	21
6	18*	19
	21	21
	21	21
7	20	20
	22	22
	21	21
8	21	21
	21*	22
	22	22

Day	Mercury in glass, suspended Thermometer °C	Grant Recorder Thermistors °C
9	22	22
	23 *	24
	23	23
10	20	20
	22	22
	21	21
11	19	19
	21	21
	21	21
12	20 *	21
	22	22
	21	21

The three figures given for each day were recorded at 7.30 a.m., mid-day and 5.30 p.m. respectively.

* indicates that the mercury in glass, suspended thermometer gave a different recording from that of the Grant recording thermometer.

SOIL ANALYSIS - Figures given are means for 1969-1971

Depth cms.	Moisture %		Colour	% by weight				pH	
	Jan.	June		gravel	coarse sand	fine sand	silt & clay	Jan.	June
HILLCREST									
0-30.4	20.0	36.3	10YR 3/2	1	21	38	40	6.5	6.4
30.4-61.0	35.4	37.9	10YR 6/3	0	9	29	62	6.4	6.4
61.0-91.5	31.5	31.8	10YR 7/2	0	4	33	63	6.5	6.5
NEWSTEAD									
0-30.4	18.4	33.0	10YR 3/2	5	10	40	45	6.4	6.3
30.4-61.0	30.5	31.1	10YR 7/4	0	8	24	68	6.4	6.4
61.0-76.0	28.5	28.9	2.5Y 7/4	0	7	30	63	6.4	6.4
76.0-91.5	17.8	14.4	10YR 7/4	0	6	39	55	6.7	6.7
TAMAHERE									
0-30.4	16.8	18.4	10YR 3/2	5	20	51	24	6.3	6.2
30.4-61.0	22.0	24.2	2.5Y 5/3	7	17	40	36	6.4	6.4
61.0-91.5	48.4	48.2	10YR 7/3	4	14	28	54	6.7	6.7

TABLE 3

CHEMICAL ANALYSIS - HILLCREST - 1966-1971

Figures are means of samples for each month taken at random from the top 15 centimetres of soil plugs.

	pH (Range)	Organic C %	Soluble N %	C/N
January	6.55(6.21-6.89)	18.31	0.62	29.5
February	6.73(6.64-6.82)	19.74	0.78	25.3
March	6.59(6.46-6.72)	16.45	0.87	18.9
April	5.98(5.18-6.88)	17.82	0.99	18.0
May	6.38(6.18-6.62)	12.27	2.18	5.6
June	5.82(4.98-6.65)	8.43	2.89	2.9
July	5.91(5.34-6.48)	3.21	3.04	1.1
August	5.77(5.56-6.13)	1.80	2.76	0.7
September	5.98(5.64-6.32)	3.45	2.15	1.6
October	5.95(5.83-6.17)	8.72	1.08	8.1
November	5.68(5.04-6.42)	10.81	0.48	22.5
December	6.27(5.75-6.90)	17.24	0.57	30.2
MEAN	6.13(5.59-6.58)	11.52	1.53	13.7
RANGE	1.05(1.92-0.99)	17.94	2.56	29.5

TABLE 4

HILLCREST SITE - pH LONG-TERM CHANGE

Figures are means for all samples from top 15 centimetres

1966	6.13
1967	6.02
1968	6.16
1969	6.18
1970	6.11
1971	6.18
1972	6.20 (January - August only)
Mean	6.13

TABLE 5

ANNUAL pH VARIATION - TOP 15 CENTIMETRES - 1970/1971

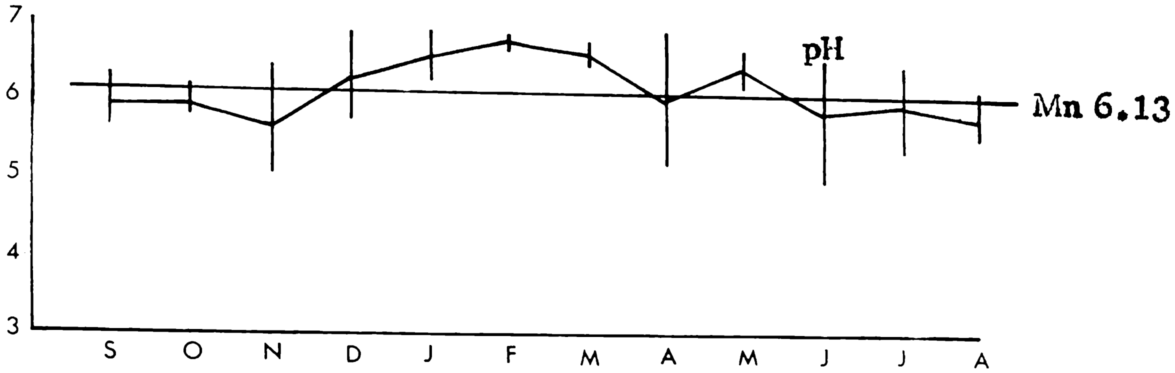
Figures are means of monthly samples

	HILLCREST	NEWSTEAD
January	6.47	6.31
February	6.70	6.65
March	6.64	6.44
April	6.52	6.51
May	5.98	5.78
June	4.98	4.93
July	5.38	5.82
August	5.87	5.84
September	6.07	5.82
October	6.17	5.90
November	6.11	5.74
December	6.42	6.01
Mean	6.11	5.98

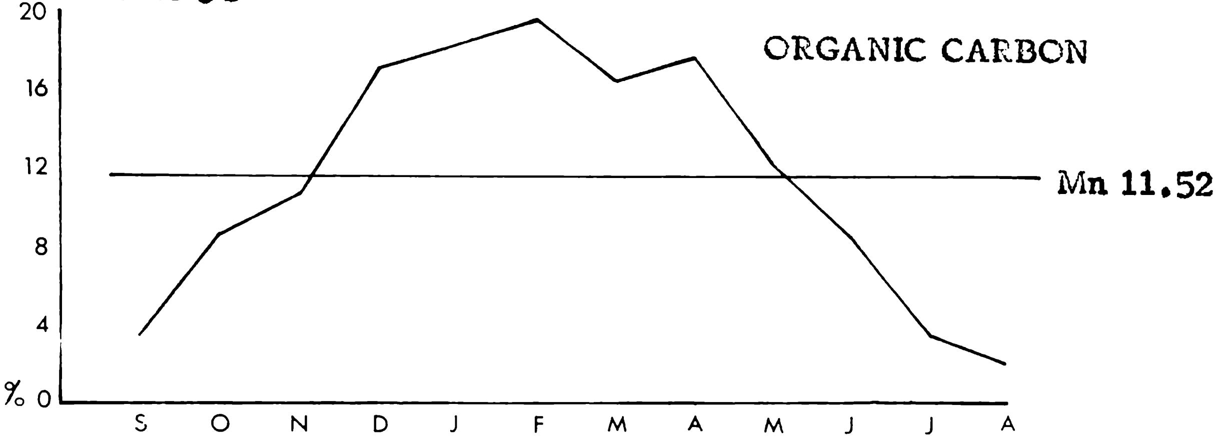
CHEMICAL ANALYSES TOP 15 CM - HILLCREST

All figures are means for 1966-1971

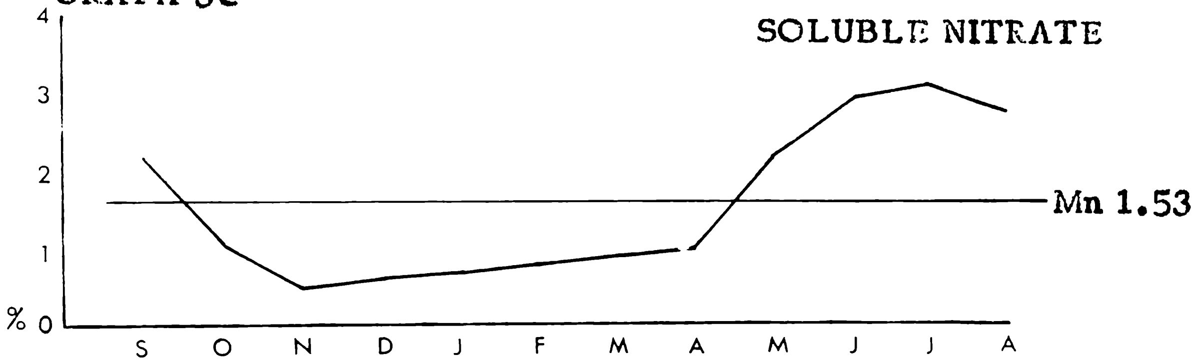
GRAPH 3a



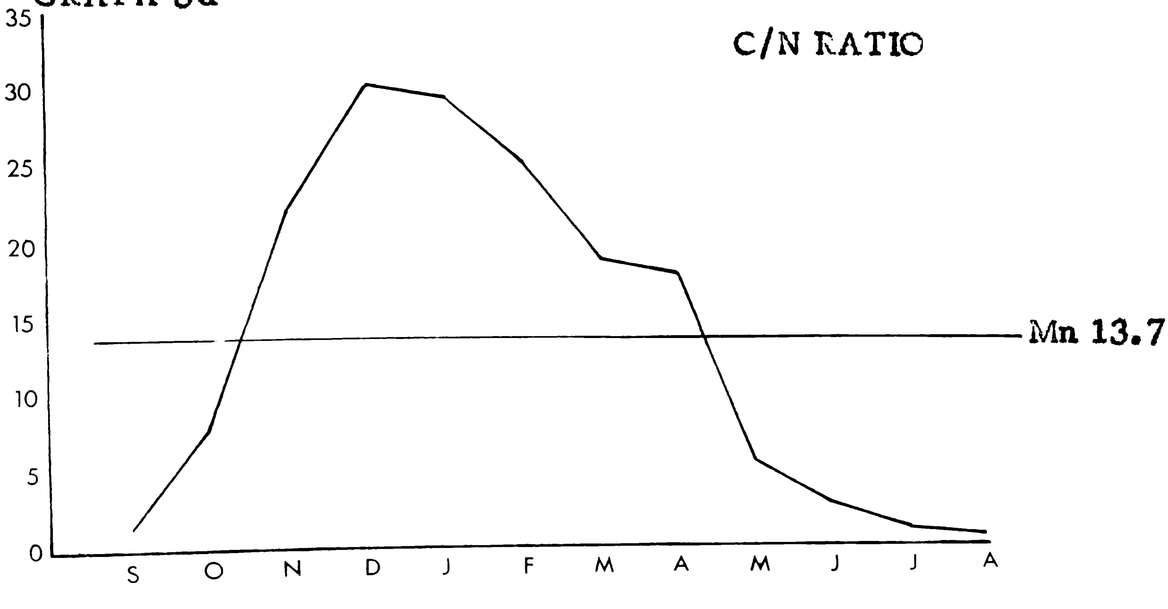
GRAPH 3b



GRAPH 3c

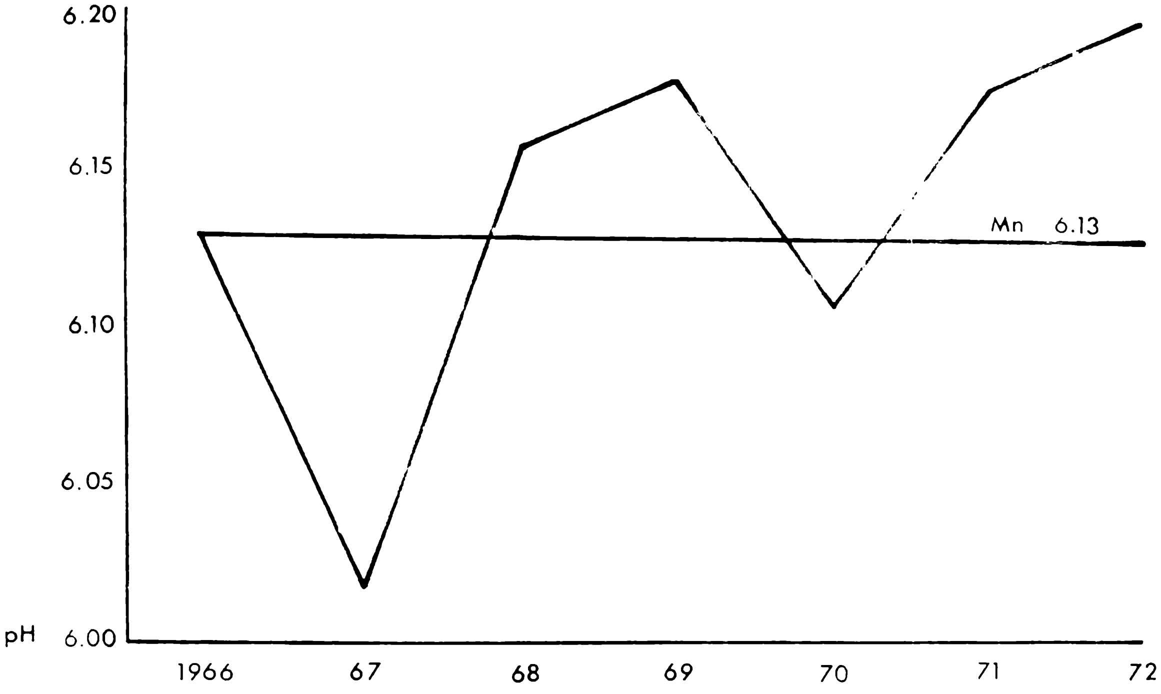


GRAPH 3d



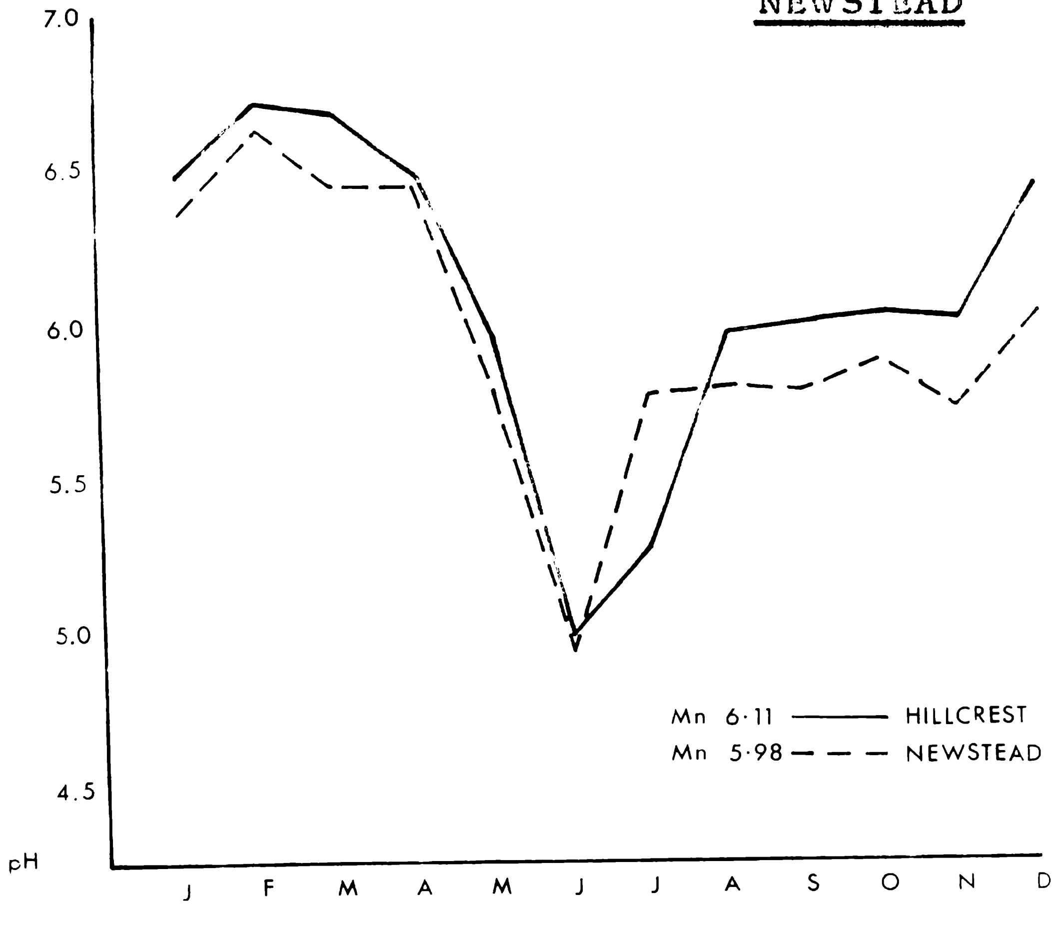
pH, HILLCREST - LONG-TERM CHANGE

GRAPH 3e



pH, ANNUAL VARIATION TOP 15 CM

GRAPH 3f 1970-71, MONTHLY MEANS - HILLCREST
NEWSTEAD



The only major physiognomic difference between the two sites is that the Hillcrest site has an annually-continuous litter and vegetation cover while that of Newstead is kept to a minimum through mowing. Air temperatures correspond in means and range. There is a difference of 4° C in interface range although the means correspond. Sub-soil means differ by 3.4° C and range by 5.0° C. The fauna on the two sites shows a corresponding difference in quantities and vertical distribution (see Section 7).

(g) Chemicals Applied to the Area

While the Hillcrest area was being used by Ruakura Agricultural Research Centre, superphosphate fertiliser was applied annually to the adjacent areas at 1200 kg/hec, but this ceased in 1963 (Parker, F. Ruakura, personal communication, 1972). No direct pH measurement occurred on the Hillcrest site before 1965, but records from pastures 2 km distant and of similar soil and floral composition show pH 5.4 - 5.6.

From the time that the Hillcrest area was taken over by the South Auckland Education Board (with one exception) no fertilisers were applied. This exception was fertiliser applied to the south end of the grounds on 6 May, 1970. As far as can be ascertained, the fertiliser was spread no closer than 200 m to the south of the Hillcrest site. At the time a very light south-east wind was blowing. The fertiliser (Dracco - lime, superphosphate, ammonium sulphate) was applied at the rate of 377 kg/hec. Because of the wind drift, some contamination of the site may have occurred, but no appreciable effect on the biota could be observed. Sampling had occurred 5 days before the application date and 23 days later: comparison of growth rate of plants and numbers of biota showed no significant changes.

(h) <u>The Effects of Grazing, Mowing</u>

No grazing has occurred on the Hillcrest site since 1963. The beginning of September, 1966 was the last time when the Hillcrest site was mowed. The long-term effects of lack of mowing and grazing can be observed by perusal of the results in Table 12 and comparison with the Newstead and Tamahere sites.

In late September, 1966 as the Hillcrest site was being set up, an area of pasture land beside the site was sampled using multi-point analysis, showing, in fact, that the two areas were very similar in floral composition. When the two areas are compared at the end of 1972, the differences can be seen.

Basically, mowing removes the ranker grasses such as Yorkshire fog, suppresses the tall growing plants such as dock, and favours the growth of soft annuals and rosette plants. A litter layer cannot be built up as a "buffer zone" giving protection to the soil-vegetation interface against extreme variations in temperature and moisture content. Similar long-term effects have been observed in the Tamahere and Newstead areas which are situated at the side of school grounds. Neither of these plots have had fertilisers applied to them in the last 10 to 15 years, although without doubt some wind drift of fertiliser will have occurred from adjacent farms. Systematic mowing of the areas is carried out over the 12 months of the year, but no grazing has occurred.

SECTION 5 : A STRUCTURAL ANALYSIS OF THE COMMUNITY

(a) Introduction

Competition is a term used widely and with various meanings in the ecological literature. In some instances, the term is defined so inclusively that it becomes synonymous with the struggle for existence or adaptation of the species. In this sense, the term denotes the sum total of the interplay of longevity and vitality factors of all kinds, favouring one species at the expense of another. So used, competition may involve space, food or nutrients, light, waste material action, predation, susceptibility to carnivores and disease, or any other type of mutual interaction - in short, it is an interaction between two or more species populations which adversely affects their growth and survival (Elton, 1946; Odum, 1959).

In a much more narrow sense, competition is defined as an active demand in excess of the immediate supply of material or condition on the part of two or more organisms; it is the endeavour of two or more organisms to gain the same particular thing, or to gain the measure each wants from the supply of a thing when that supply is not sufficient for both (Clements and Shelford, 1939).

It appears preferable that the concept be re-stated succinctly and in such fashion that it be given a simple and unequivocal meaning. The author proposes that for this study competition be defined as 'the process by which one organism affects another through the utilisation or removal of some resource of the environment'. In this sense, competition is simply a process through which one organism inhibits the availability of one or more factors essential for another organism's way of life.

As an example to illustrate this definition, the relationships of biota to water content can be considered. There is no question that soil organisms are profoundly influenced by the quantity and quality of the water available to them; that they need water; that small changes in the water content may alter soil microhabitats or change nutrient availabilities. Changes in the amount of soil water are brought about by factors other than competition between organisms, or the using up of a limited supply by one organism, thus leaving an insufficient supply for a second organism.

In the presence of an initially favourable water supply in the soil, depletion of that supply is caused by factors such as evaporation or the evapo-transpiration carried out by plants. Plants, growing in a soil, quite often are the agents responsible for the removal of a favourable water supply initially stored therein. Plants may correctly be said to compete for water. As shown by Clark (1969), the lack of establishment of new young plants in an already established area may be related as much to water loss as to crowding or competition from already established plants. The author feels that some of the changes in plant distribution in the Hillcrest site may be explained in the way Clark has suggested.

(b) <u>A measure of the similarity of plots, using floral composition in each plot as the unit of measure.</u>

Using the formula of Simpson (1960), a biotic resemblance factor was calculated, i.e., $BRF = \frac{x}{(m + n) - x}\ \%$

Where m = the number of species in one area

n = the number of species in the second area

x = the number of species in common to the areas, and

BRF = the Biotic Resemblance Factor.

The greater the percentage figure, the closer is the similarity between plots.

SITE SIMILARITY

	1968	1972
Hillcrest/Newstead	46.6%	56.0%
Hillcrest/Tamahere	43.0%	52.0%
Newstead/Tamahere	80.0%	80.0%

It should be noted, however, that the increased similarity between Hillcrest and Tamahere, and Hillcrest and Newstead in 1972 is the result of the elimination of plant species through competition, rather than the accumulation of new species in the Hillcrest site. (See Table 11.)

The parallel sampling plot at the Hillcrest site shows a Biotic Resemblance Factor of 46.6% in 1968 and 47.0% in 1972 when compared with Newstead, and 43.0% and 43.2% when compared with Tamahere.

(c) Comparison with other studies on grassland soils.

Much of the basic background work on soil structure and chemistry has been completed in Europe where soil biology had its beginnings, but in New Zealand to the present day the basic work is far from complete. As Luxton (1968) has pointed out, "information on the systematics of some important groups of soil organisms (in particular, nematodes, enchytraeids and mites) is scarce or almost completely lacking. Until this ground-work has opened out many aspects of soil biology must be at best incomplete. However, in recent years, soil biology has tended towards a more ecological approach and this trend is likely to continue."

The type of survey which this author has carried out is difficult to compare directly with the research of other workers for a number of reasons. Few surveys have extended to such a time span (the majority of work surveys a twelve month period); most work concentrates upon either the flora or the fauna of an area; and methods of sampling and extraction differ widely.

Recent work within New Zealand includes that of McMillan (1969) who made a thirteen month census of the acarine and collembolan fauna of two pastures near Wellington. The two sites were on sloping hillsides of a fine-textured silt loam. The sites were not manured during the thirteen months of the study. McMillan established peaks for numbers of Acarina and Collembola during the period and indicated some correlations of occurrence between some species. However, as he states, "unfortunately, knowledge about the biology of the great majority of soil-inhabiting arthropods is insufficient to enable the interpretations of any associations with unequivocal accuracy. These results, however, may serve to support or initiate direct observations on the biology of certain species, which may further elucidate their ecological requirements."

Concurrently with McMillan, Adams (1971) looked at the ecology of some soil Collembola in the same area. She was concerned with species composition and population dynamics in the soil profile during a twelve month period. As far as this author can ascertain, no long-term study has as yet been carried out.

Lee (1968) collected soil samples from a variety of soil types throughout New Zealand during March, April and May, 1960, to give a broad general picture of the distribution, population numbers and ecological association of fauna with soil type.

Dhillon and Gibson (1962) made a study of the Acarina and Collembola of undisturbed old grassland in Great Britain over a fourteen month period. Samples were taken at monthly intervals - each sample measuring 4.8 cm diameter and to a depth of 15.0 cm. Extraction was effected using modified Tullgren funnels. They concluded that :-

1. The populations of both Collembola and Acarina fluctuated with time and marked differences occurred in the patterns of variation shown by different species. There was no evidence that the changes as a whole bore any relationship to the fluctuations of soil temperature, moisture, pH or organic content.
2. By far the greatest numbers of fauna occurred in the top 7.6 cm of soil.
3. The vertical distribution of the fauna showed an overall similarity to the distribution of pore space in the soil.
4. Significant changes occurred in the vertical distribution of almost all species, but showed no seasonal regularity. These changes took place at depths where soil conditions were comparatively stable and could not be related to any variations in the soil moisture, temperature, pH or organic content.

It would seem to this author, from their findings, that in the soil of fully-established grass fields under British climatic conditions, temperature and humidity are likely to exert an overriding influence only near to the surface, and that at lower levels, the numbers and distribution of Acarina and Collembola are more likely to be the cumulative influence of small changes in several soil factors. It should be made clear, however, that these fluctuations and the conclusions which Dhillon and Gibson drew from them were the results of one annual cycle only. Also, there is no evidence in their work that enough emphasis has been placed on the importance of vegetation and litter cover and its effect upon microclimate.

Salt, Hollick, Raw and Brian (1948) sampled, over a period of 27 months, a heavy clay pasture in Britain under normal agricultural use. Single samples were taken each month from each of 20 positions, and arthropods extracted by high pressure washing through sieves and flotation in magnesium sulphate solution. The apparatus and method were designed for wireworm extraction, and, as they state, "The method used did not serve to collect the entire population of some of the smaller forms. Further, no attempt was made to identify all of the several thousands of individuals collected." In spite of these reservations on their part, some worthwhile conclusions were reached:

(a) Coefficients of dispersion were calculated on collections of Thysanura, Hemiptera, Coleoptera, Diptera, Symphyla, Chilopoda, Protura, Collembola and Acarina, i.e., all soil-dwelling groups in which the numbers were large. In every case the coefficients were significantly greater than unity, showing, in so far as this statistical test is valid, that distribution is non-random and aggregated. (It was for this reason that this author did not produce coefficients of dispersion during the period of research. It is doubtful whether new information could have been added to present knowledge.)

(b) The majority of soil-dwellers occur in the top 6 cm of soil, and there is a close relationship between total bulk of each animal and depth of vertical distribution. The fauna which occurs below the 6 cm level is small in numbers and body bulk.

No attempt was made to correlate total numbers with floral content of the area and only brief mention was made of edaphic factors.

(d) Association between environmental factors.

Any measurement made of an organism indicates the joint action of many environmental factors with each other and with the heredity of the organism. In one sense, every organism is unique, for it is inconceivable that exactly the same interplay of heredity and environment could be duplicated in nature. Not only is the result of any combination of forces on the organism unique, but it is unpredictable as well. All other things being equal, a rise in temperature may raise the metabolic rate of an organism by a given amount and affect its pattern of life; but all other things are never equal and the effect of a rise in temperature may be quite different when combined with other variable forces acting on the organism. This principle of unpredictability, if pursued to its obvious end, prevents the biologist from assigning to any single factor in the environment a relative role in the determination of observable phenomena. In this sense, all factors are equally important and interrelated in determining the life pattern of an organism, and any attempt to separate the effects of these forces is biologically unrealistic.

In a more restricted sense, however, various determining factors do affect an organism to different degrees, and the relative importance of each variable is a valid object of biological inquiry.

Measures of correlation demonstrate only that two variates are shown, or are not shown, by a given example to vary in such a way as to tend to maintain a definite relation to each other. They tell nothing about the cause of the relationship but reveal only its existence or the lack of reliable evidence for it. There is a danger, in passing from these numerical results to biological conclusions, that the relationship may be misunderstood, or may without due consideration be assumed to represent cause and effect. In most cases, however, the more egregious blunders can be avoided through the use of common-sense guided by different methods of data comparison. The relations between pairs of variates may in some cases, however, be so obscure that considerable analysis is necessary to differentiate cause and effect or to distinguish a real correlation from one which is spurious - being caused not by any true relationship between the variates considered but by their relationship to a third variate that has been omitted from the problem.

To investigate the relationships (and possible association) between variates in an enclosed pasture area, data were utilised from the Hillcrest area. Details of flora, fauna, soil conditions and meteorology were recorded for 1967 and 1968. This time period was chosen because of the great change in floral content over the two year period as compared with the relative ecological "stability" after this time.

Using the University of Waikato computer IBM 1130, a mainline programme was composed using the IBM scientific subroutine package. Details of this programme are stored with the University of Waikato computer centre. Correlations were obtained between pairs of factors for each sampling period over 24 months.

Full details of correlations occur in Appendix 4; however, the author has selected examples for discussion :

1. Mesostigmatidae show marked positive relationships with Collembola (+0.46), stratiomyid larvae (+0.57), Mollusca (+0.58), Enchytraeidae (+0.46), pH (+0.56) and Agrostis tenuis (+0.47). A slight positive relationship is shown with depth of litter (+0.29). There are substantial negative

relationships with scarabid larvae (-0.56), *Lolium perenne* (-0.54), *Achillea millefolium* (-0.56), *Plantago major* (-0.52), *Ranunculus sardous* (-0.41), *Trifolium repens* (-0.40) and height of vegetation (-0.47).

Climatic data show a marked negative correlation, particularly mean R.H. (-0.64), mean air temperature (-0.61), minimum surface temperature (-0.61) and minimum soil temperature (-0.60).

2. Collembola show a high positive correlation with stratiomyid larvae (+0.75), and substantial positive relationships with Mesostigmatidae (+0.46), Mollusca (+0.68), pH (+0.59), and *Agrostis tenuis* (+0.52). High negative correlations are shown with *Lolium perenne* (-0.71), height of vegetation (-0.70) and all climatic data (range: -0.72 to -0.79), particularly maximum surface temperature (-0.79). Marked negative relationships occur with *Plantago major* (-0.69) and *Ranunculus sardous* (-0.58). The depth of litter has little relationship with the presence of Collembola (+0.10).

3. The Lumbricidae show a high positive correlation with *Dactylis glomerata* (+0.89) and a substantial positive relationship with *Ranunculus sardous* (+0.43). Positive and negative correlations with other environmental factors are negligible (from +0.20 to -0.20).

4. Scarabid larvae show a marked positive relationship with *Achillea millefolium* (+0.44) and *Trifolium repens* (+0.57). There is a substantial negative correlation with Mesostigmatidae (-0.56), Mollusca (-0.46), Enchytraeidae (-0.47), *Mentha pulegium* (-0.40), depth of litter (-0.51) and pH (-0.59). Slight negative relationships are indicated with Collembola

(-0.37) and Agrostis tenuis (-0.33). There is a low positive correlation with climatic conditions.

5. Stratiomyid larvae have high positive relationships with Collembola (+0.75) and Mollusca (+0.83). Substantial positive relationships occur with pH (+0.58), Mesostigmatidae (+0.57), Paspalum paspaloides (+0.63), Agrostis tenuis (+0.52) and a low positive relationship with Enchytraeidae (+0.32). Very high negative relationships occur with Lolium perenne (-0.88), Plantago major (-0.84), Ranunculus sardous (-0.71), height of vegetation (-0.86) and a substantial negative relationship with Dactylis glomerata (-0.41). There is a very high negative correlation with weather data, notably mean air temperature (-0.99), mean minimum air temperature (-0.98) and minimum soil temperature (-0.98).

6. Litter depth has a very high positive correlation with Enchytraeidae (+0.87) and pH (+0.71). A marked positive relationship is shown with Mollusca (+0.42) and Mentha pulegium (+0.42). There is a slight positive correlation with Mesostigmatidae (+ 0.29), and Holcus lanatus (+0.26). Marked negative relationships occur with scarabid larvae (-0.51), Trifolium repens (-0.45), Achillea millefolium (-0.52) and Paspalum paspaloides (-0.63).

7. Vegetation height shows very high positive correlations with maximum soil temperature (+0.88) and minimum soil temperature (+0.88).

It would be very tempting to extend the correlations shown into a cause and effect relationship. However, as stated previously, the associations between pairs of variates whether positive or negative may be due to the influence of a third or further variate which has been omitted from the problem.

It seems, nevertheless, that a high positive correlation exists between the presence of surface-dwelling invertebrates and the height of vegetation. As well as this, the height of vegetation has a marked positive correlation with maximum and minimum soil temperatures.

These facts alone seem sufficient to show (at least for Hillcrest in 1967 and 1968) that the condition of the soil-vegetation interface is strongly correlated with the state of the vegetation which, in turn, affects the living conditions of interface organisms.

SECTION 6 : SEASONAL FLUCTUATION

(a) Introduction

The fluctuation in numbers of groups of organisms in response to environmental factors is a fact established by many authors. Exactly how soil animals respond to changes in environmental variation is not well known, but most authors indicate that the major effective factors are variations in soil moisture and temperature. In this section, a description is made of the major fluctuations occurring in several faunal groups at the Hillcrest site over a seven-year period.

The number of animals in the soil of an area varies during the year and the following table gives estimated total numbers of all microarthropods in various habitats. It must be noted at this point, however, that a direct comparison of numbers is difficult because some authors sampled once only (Salt et al - 1948, 1949), while others did not sample over a full annual cycle (Sheals - 1957).

In some cases, the figures represent a mean for the annual cycle, others are the maximum for a particular time and some authors do not indicate clearly what their figures state. To attain some degree of resemblance, the author has assumed that sampling occurred to the same depth, i.e., 15.0 cm, and that sampling was random and uniformly distributed.

(b) The total fauna shows a bimodal distribution of population numbers. A lower population occurs in late winter/early spring (August/September) because of the temperature lag between the air and the soil. On the average the sub-soil temperature is 3.5° C

TABLE 6 : NUMBERS OF SOIL ANIMALS

Author	Habitat	Soil type	Method	Total Numbers Millions/ Hec.	
Weis-Fogh (1947-48)	old pasture	sandy soil	Berlese	320	Max
Salt et al (1948-49)	old pasture	clay loam	flotation (0.1 mm. mesh)	2630	Max
Sheals (1957)	old grassland	heavy, wet loam	flotation (0.15 mm. mesh	570	Mn
Haarløv (1960)	"level pasture"	dry, sandy loam	Tullgren	2880	Max
Dhillon & Gibson (1962)	old pasture	light, sandy loam	Tullgren	580	Mn ?
MacFadyen (1962)	pasture	heavy, wet loam	modified Tullgren	2040	Max
Davis (1963)	old pasture	heavy clay	flotation (0.15 mm. mesh)	360	Mn ?
Adams (1964-65)	pasture	silt clay loam	Tullgren	1000	Max

Note: Table, in part, after Wood (1966).

For comparison:

Rosenberg 1966-72	pasture Hillcrest	sandy loam	modified Tullgren	860	Mn
Rosenberg (1970-71)	pasture Newstead	dry, sandy loam	modified Tullgren	300	Mn
Rosenberg (1970-71)	pasture Tamahere	sandy loam	modified Tullgren	740	Mn

lower than the air at mid-day. The late spring/early summer peak in November/December occurs as soil/vegetation interface temperatures rise, vegetation growth increases and a litter layer accumulates. The population figures reach their lowest point for the year in January as the top soil loses its moisture, but in late autumn/early winter (May/July), the population reaches its maximum for the year. This peak may be 12% higher than during the late spring period. The late autumn peak coincides with the maximum accumulation of litter. However, by August the peak of population is reduced by 20% as colder, moister conditions occur (see Graphs 4o,5o).

(c) Lumbricidae

At Hillcrest, the maximum numbers of earthworms occur in the top soil during June, July and August when the totals may be 42% greater than the mean for the year. The minimum occurs in February when the numbers are 20% below the mean.

At Newstead, maximum numbers occur also during June, July and August when the numbers are 30% above the annual mean. The minimum numbers occur in February and March, when they are 36% below the mean.

Cocoons are produced throughout the year, but maximum numbers are produced in October (up 15%) and minimum numbers in January (down 19%). At Newstead the maximum cocoon numbers occur in October (up 15%) and are at a minimum in February and March (down 22%).

(d) Enchytraeidae

At Hillcrest, the maximum numbers occur in June, July and August when the numbers are 16% higher than the annual mean.

The minimum occurs in February and March, when the figures are 12% below the annual mean.

At Newstead, the maximum occurs similarly during June, July and August (up 16%) and the minimum occurs in January, February and March (down 27%).

(e) Mollusca

The maximum numbers at Hillcrest (up 37% and the main breeding season) occur in November, the minimum numbers in April (down 28%). At Newstead, the maximum numbers (up 35%) occur in November and the minimum in February (down 80%). Egg production occurs in two peaks of equal magnitude at both Hillcrest and Newstead, i.e., May and November.

(f) Crustacea

At Hillcrest, isopods and amphipods are present throughout the year but the maximum numbers occur in October and November when the numbers are 16% higher than the annual mean. The minimum occurs in January and February when the numbers fall to 27% below the annual mean.

At Newstead, the maximum occurs in November (up 15%) and the minimum in December, January and February (down 84%).

(g) Myriapoda

The Hillcrest maximum occurs in March (up 9%) and the minimum in October (down 12%). At Newstead, the maximum occurs in August (up 8%) and the minimum in January and February (down 61%).

(h) Arachnida

At Hillcrest, the maximum numbers of spiders occur in January, February and March: 63% greater than the annual mean. The minimum occurs in September and October when the numbers are 35% below the annual mean.

At Newstead, the maximum numbers are present in February and March (up 68%) but minima occur at two periods - January (down 12%) and September (down 32%).

(i) Acarina

June, July and August at Hillcrest have the maximum numbers (up 42%), and during September the minimum is reached (down 48%).

At Newstead, the maximum numbers (up 38%) are present in June, July and August but minima occur during January (down 52%) and September (down 45%).

(j) Collembola

The numbers of Collembola at Hillcrest show two maxima i.e. March (up 18%) and August (up 120%). The minima occur in June (down 14%) and October (down 12%).

At Newstead, a single peak is recorded in August (up 89%) and minima occur in January (down 62%) and October (down 12%).

(k) Staphylinidae

At Hillcrest, the maximum numbers occur in June (up 12%) and the minimum in October, when the numbers are 4% below the annual mean.

At Newstead, the maximum numbers occur in May and June (up 15%) but two minima occur - February (down 2%) and October (down 6%).

(l) Carabidae

In both Hillcrest and Newstead sites, the patterns of seasonal distribution are very similar, i.e., Hillcrest adults attain a maximum in August and September (up 12%); Newstead at the same time but up 11%. Minimum numbers occur in May at Hillcrest (down 4%) and May at Newstead (down 7%). The carabid larvae reach a maximum at Hillcrest during December, January and February (up 57%) and a minimum in June and July (down 12%). At Newstead the maximum occurs in December and January (up 56%) and a minimum during June and July (down 13%). In both sites, eggs are deposited during October, November and December, with a major peak in late November - early December.

(m) Scarabidae

The seasonal distribution is very similar at both sites. Adults are present just below the surface or resting on vegetation during October and November at both sites. At Hillcrest, the maximum number of larvae occurs during July and August (up 60%), the minimum in November (down 22%). At Newstead, the maximum number of larvae occurs during July and August as well (up 58%) and the minimum during November (down 24%).

(n) Elateridae larvae

At Hillcrest, the maximum number of larvae present occurs in June (up 23%) and the minimum during February and March (down 14%).

At Newstead, the maximum occurs in June (up 27%) but the minimum is in January and February (down 20%).

(o) Chalcidae

In January and February, the chalcids reach their maximum numbers (up 12%) and their minimum numbers during June, July and August (down 18%).

At Newstead, February and March contain the maximum number (up 10%) and July the minimum (down 14%).

(p) Formicidae

The numbers of ants do not fluctuate markedly during the annual seasonal cycle. At Hillcrest, the maximum numbers present occur during February, March and April (up 5%) and the minimum in November (down 8%). Newstead shows a similar pattern with maximum numbers occurring in April (up 5%) but minimum numbers are present in January and February (down 11%).

(q) Stratiomyidae

The larvae at both sites shows a very similar pattern, i.e., at Hillcrest the maximum numbers occur in November and December (up 14%) and the minimum in October (down 16%), while at Newstead the maximum is in November and December (up 15%) and the minimum in October (down 17%). The puparia, however, show a different pattern. At Hillcrest the maximum numbers occur in March (up 57%) and at Newstead, also in March (up 55%). The minimum numbers occur during October at Hillcrest (down 58%) and December at Newstead (down 70%).

(r) Other groups

If the figures for all other groups are calculated together a fairly clear maximum occurs at both sites during August, September and October; Hillcrest (up 12%), and Newstead (up 11%). The minimum occurs in December, January and February at Hillcrest (down 8%), but during January, February and March at Newstead (down 14%).

SUMMARY

The author has placed the most common fauna into groups according to the habitat in which each most frequently occurs.

1. The Scarabidae (notably Costelytra zealandica Wh.) and Stratiomyidae (notably Altermetaponia rubriceps Macq.) are placed separately, because although they may be present in some considerable numbers, they are "periodic" forms. (Note Kevan's 1962 classification.)

2. The Mollusca are considered separately due to their vertical dispersion. They may occur 6 cm below the surface or move freely over suface vegetation. They include : Agriolimax reticularis Müller, Helix aspersa L., Limax maximus L., and Thallasohelix zelandiae Gray.

3. The "burrowers" include the Lumbricidae (two species are present : Allolobophora caliginosa Savig. and Lumbricus rubellus Hoff.), as well as Enchytraeidae. These two groups live within the top 6 cm of the soil but can burrow to greater depths. (In March, 1971 at Hillcrest a single specimen of Allolobophora was found at a depth of 92.5 cm.) Lumbricus was generally confined to the top 5 or 6 cm of soil.

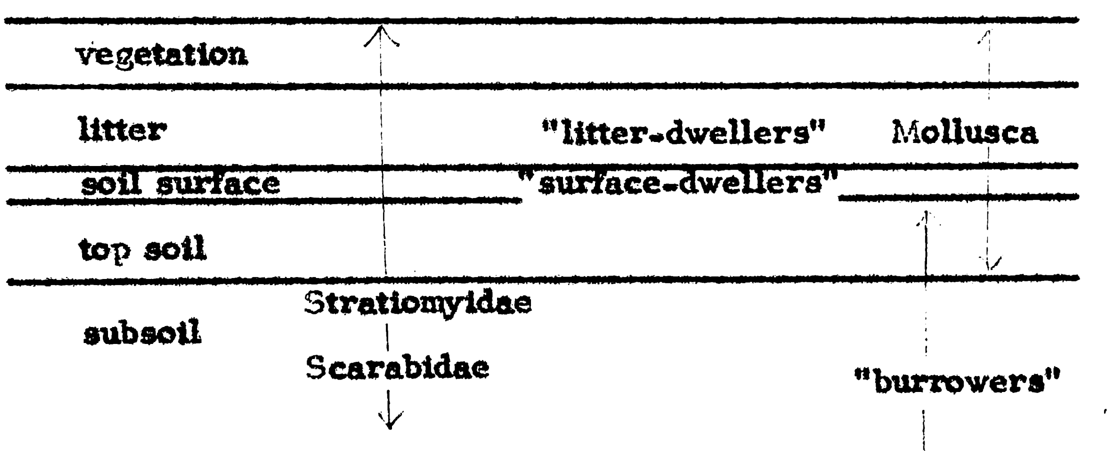
4. The "litter-dwellers" occur at the soil/vegetation interface where a gradient of environmental conditions exists in depth of litter, amount of light penetration, moisture and temperature. The commonest species present include the isopod Porcellio scaber Latr. (although never numerous during the study period), the amphipod Orchestia sp.,

Chilopoda-*Geophilus* sp., Acarina-*Oppia* sp., *Punctoribates punctum* Koch, *Platynothrus sculptus* Koch, and *Scutovertex sculptus* Michael. The most common Collembola was *Entomobrya nivalis* L.

5. The "surface-dwellers" live mostly in soil interstices or burrow within the top 2 or 3 cm of soil. They include most commonly, the Araneida-*Lycosa* sp., Carabidae-*Trichosternus difformipes* Bates, Staphylinidae-*Creophilus oculatus* Frabricius, Elateridae - exact identification uncertain but probably *Conoderus exsul* Broun, and Formicidae Monomorium antarcticum White.

Many other groups appear from time to time, particularly as transients on or within the vegetation. Some of the commoner species are included in Section 11, with notes concerning their occurrence and habits.

CLASSIFICATION OF SOIL FAUNA ACCORDING TO HABITAT



Not to scale.

When a comparison is made between the populations of the Hillcrest and Newstead sites (Table 8), it can be seen that the times when groups are at their maximum population numbers coincide closely in the two areas, except in January and February. This is the time when the vegetation is being removed regularly from Newstead, but a litter layer is present at Hillcrest giving protection to the soil/vegetation interface. This litter layer dampens down the temperature fluctuations of the interface and topsoil, and also helps to retain a greater moisture content in the upper soil layers (see Graphs 1d, 2d). Where the vegetation is removed by regular mowing, and litter is minimal, the number of organisms is reduced.

If the two sites are compared with respect to times when groups have attained their maximum and minimum population numbers (see Graphs 6a, b), the following can be seen :

COMPARISON OF NUMBERS OF GROUPS AT MAXIMUM POPULATION LEVELS WITH NUMBERS OF GROUPS AT MINIMUM POPULATION LEVELS

Hillcrest	2:3	1:7	4:3	0:1	1:0	2:3	2:1	2:1	1:2	1:6	3:1	0:1
Newstead	1:8	0:9	1:1	0:0	1:1	1:1	2:1	2:0	1:2	1:3	6:1	0:2
	Ja	F	Mc	Ap	M	Jn	Jy	A	S	O	N	D

In January and February at Newstead, the total number of groups attaining maximum population is one. The number of groups at their minimum is 17. The figures for the corresponding period at Hillcrest are 3 and 10. Again, by examination of Table 8 and using the author's habitat classification, it can be seen that the major groups affected by vegetation and litter removal (with its meteorological consequences) are the "litter-dwellers", Mollusca and "surface-dwellers".

It would seem, therefore, that a litter layer plays an important role in preserving the stability of population groups during an annual cycle, giving protection against temperature and moisture fluctuations as well as providing an additional number of ecological niches not available when vegetation is regularly removed.

TABLE 7

VARIATION - TOTAL FAUNA IN TOP 15 CM OF SOIL

HILLCREST SITE - 1967/1971

MONTH	MN	MX	MIN
January	6.9	9.6	4.2
February	8.4	10.6	5.8
March	9.6	37.1	7.6
April	12.1	13.1	11.1
May	13.1	15.3	10.8
June	15.5	16.0	15.0
July	13.3	14.3	12.3
August	11.3	12.1	10.6
September	8.4	9.6	7.1
October	8.1	8.2	8.1
November	10.4	10.6	9.9
December	13.1	18.0	8.1

All figures in millions/ha.

Mean figures given are means for all samples over 5 years.

TABLE 8

SEASONAL VARIATION FAUNA - HILLCREST AND NEWSTEAD - 1970-1971

FAUNAL GROUP	HILLCREST				NEWSTEAD			
	MX	V	MIN	V	MX	V	MIN	V
Lumbricidae	Jn, Jy, A	+42	F	-20	Jn, Jy, A	+30	F, Mc	-36
Lumbricidae cocoons	O	+15	Ja	-19	C	+15	F, Mc	-22
Enchytraeidae	Jn, Jy, A	+16	F, Mc	-12	Jn, Jy, A	+16	Ja, F, Mc	-27
Mollusca	N	+37	Ap	-28	N	+35	F	-80
Mollusca eggs	M, N				M, N			
Crustacea	O, N	+16	Ja, F	-27	N	+15	D, Ja, F	-34
Myriapoda	Mc	+9	O	-12	A	+8	Ja, F	-61
Arachnida	Ja, F, Mc	+63	S, O	-35	F, Mc	+68	Ja, (S)	-12 (-32)
Acarina	Jn, Jy, A	+42	S	-48	Jn, Jy, A	+38	Ja, (S)	-52 (-45)
Collembola	Mc, (A)	+18(+120)	Jn,(O)	-14 (-12)	A	+89	Ja, (O)	-62 (-12)
Staphylinidae	Jn	+12	O	-4	M, Jn	+15	F, (O)	-2 (-6)
Carabidae adults	A, S	+12	M	-4	A, S	+11	M	-7
Carabidae larvae	D, Ja, F	+57	Jn, Jy	-12	D, J	+56	Jn, Jy	-13
Carabidae eggs	O, N, D				O, N, D			

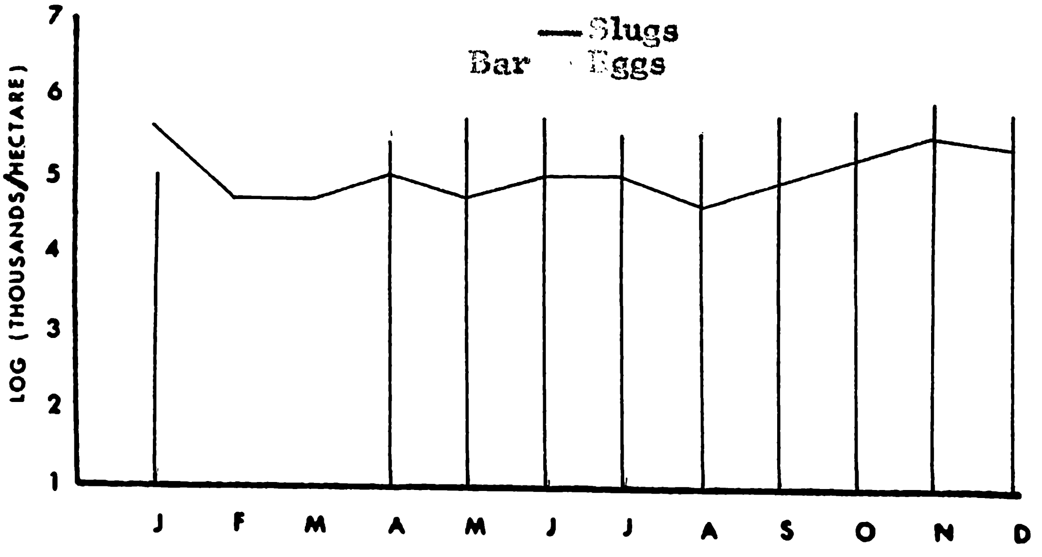
SEASONAL VARIATION FAUNA - HILLCREST AND NEWSTEAD - 1970-1971 (continued)

FAUNAL GROUP	HILLCREST				NEWSTEAD			
	MX	V	MIN	V	MX	V	MIN	V
Scarabidae larvae	Jy, A	+60	N	-22	Jy, A	+58	N	-24
Scarabidae adults	C, N				C, N			
Elateridae larvae	Jn	+23	F, Mc	-14	Jn	+27	Ja, F	-20
Chalcidae	Ja, F	+12	Jn, Jy, A	-18	F, Mc	+10	Jy	-14
Formicidae	F, Mc, Ap	+5	N	-8	Ap	+5	Ja, F	-11
Stratiomyidae larvae	N, D	+14	C	-16	N, D	+15	C	-17
Stratiomyidae puparia	Mc	+57	C	-58	Mc	+55	D	-70
Cthers	A, S, C	+12	D, Ja, F	-8	A, S, C	+11	Ja, F, Mc	-14

KEY TO THE TABLE:

1. Months abbreviated to: Ja, F, Mc, Ap, M, Jn, Jy, A, S, C, N, D.
2. All figures given are percentage variation from the mean figure for the year for each group at each site - e.g., +42 indicates that the maximum figure was 42% higher than the annual mean.

GRAPH 4a MOLLUSCA 1967

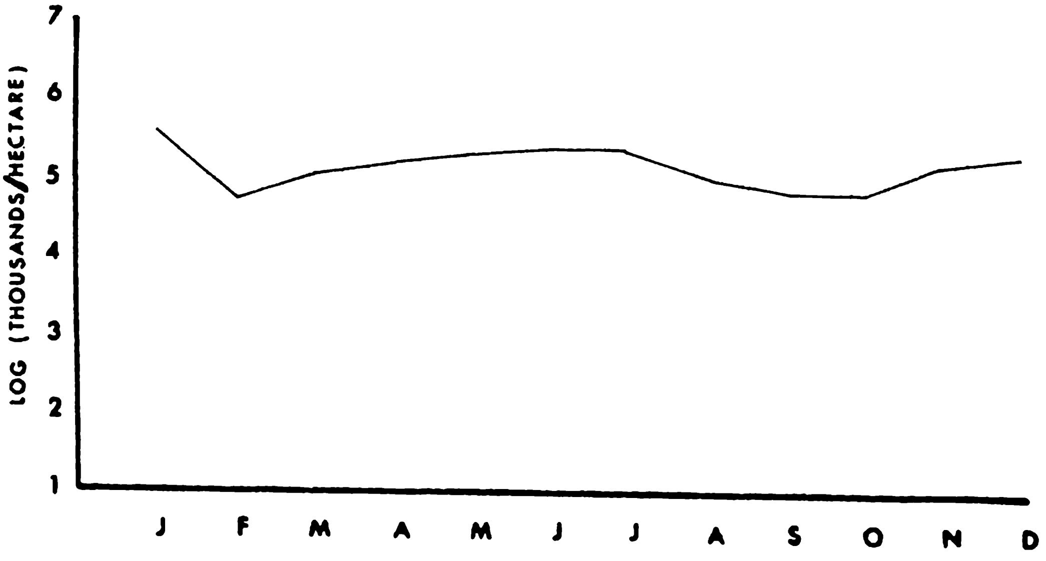


GRAPH 4b ACARINA 1967

GRAPH 4c ARANEIDA 1967

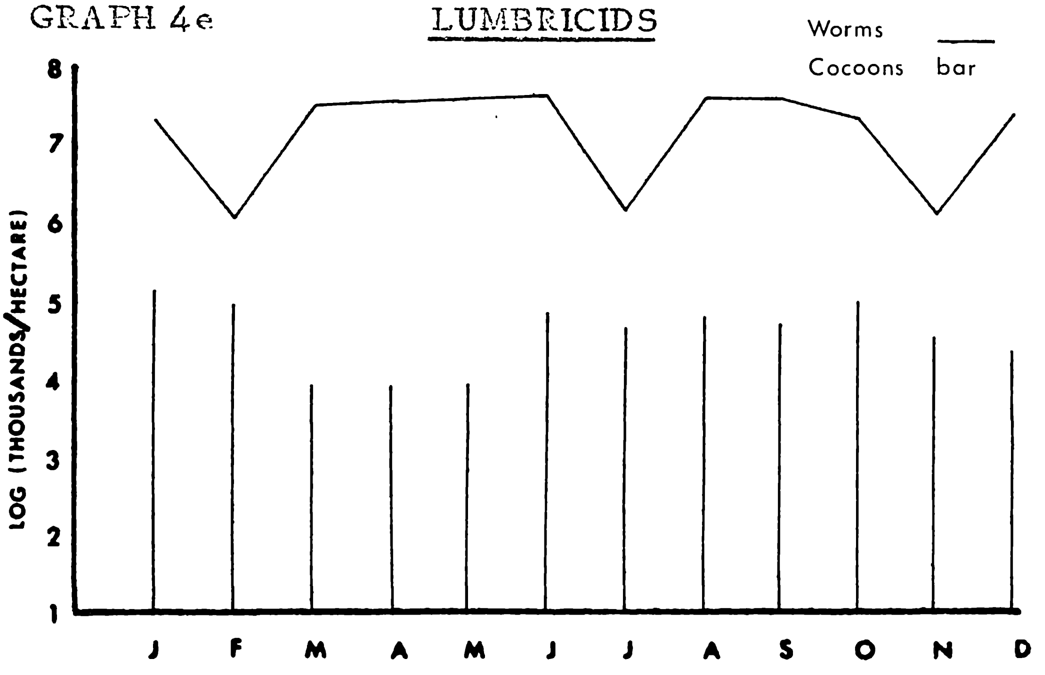
GRAPH 4d

CHILOPODA



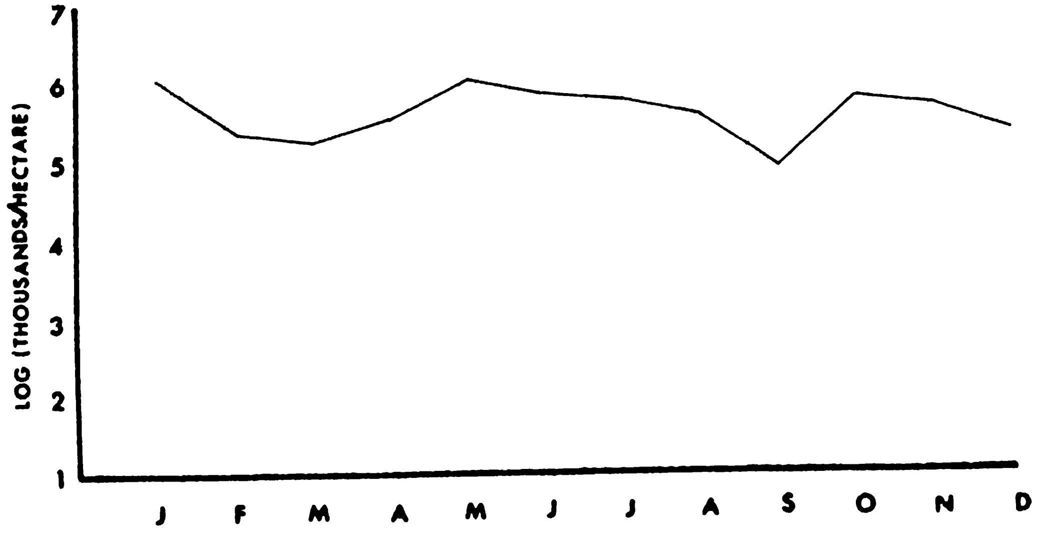
GRAPH 4e

LUMBRICIDS



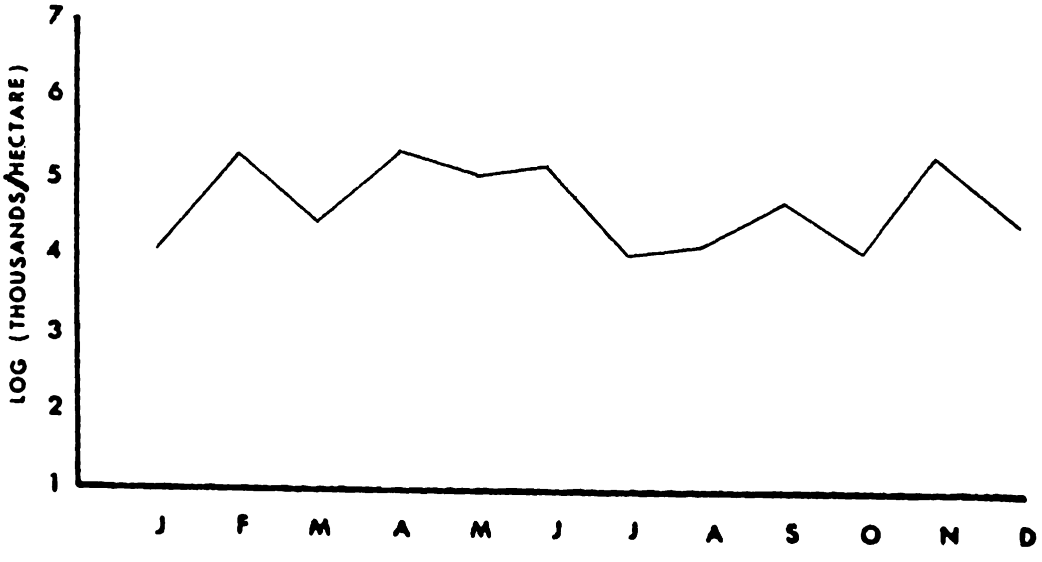
GRAPH 4f

ENCHYTRAEIDS

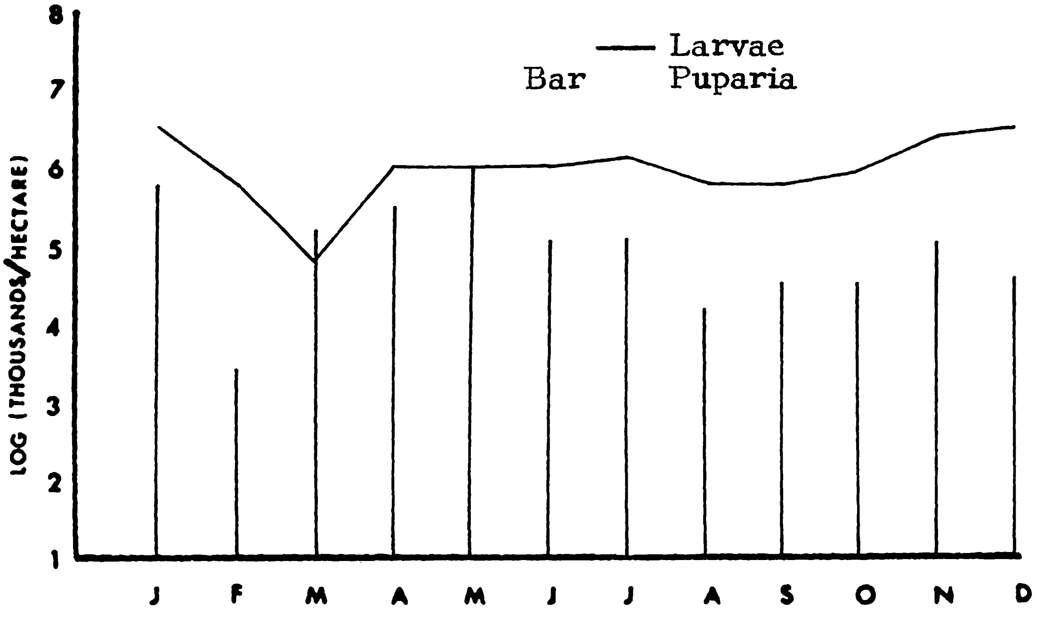


1967

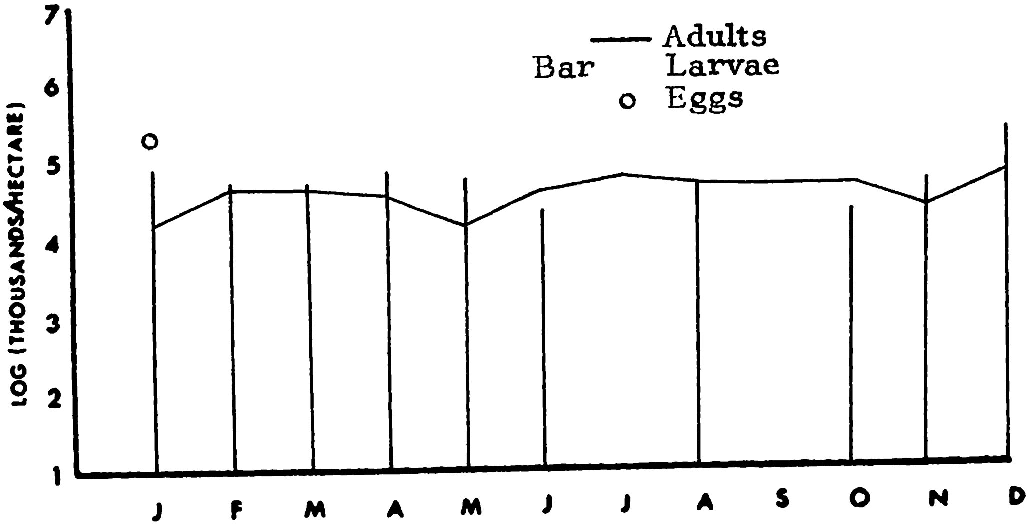
GRAPH 4g FORMICIDAE 1967



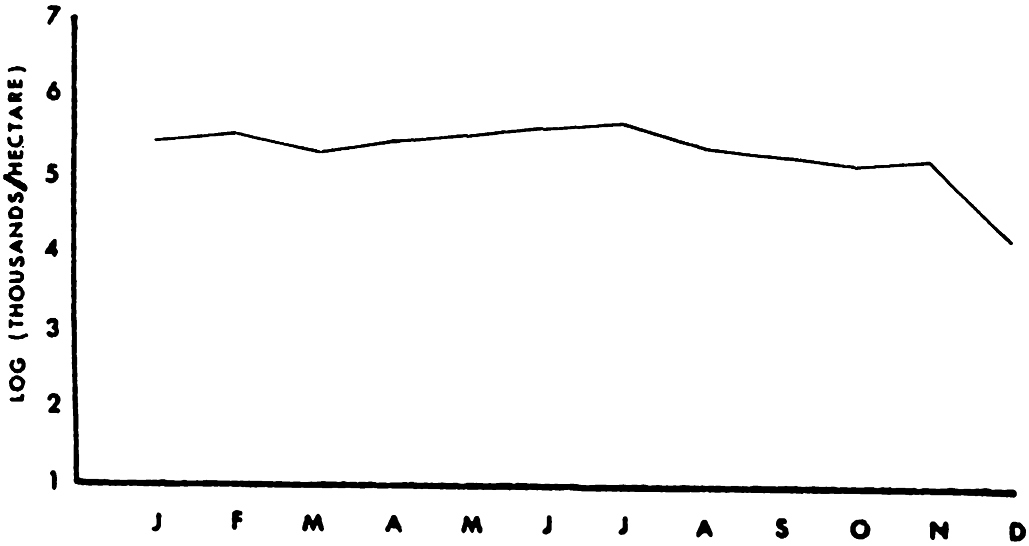
GRAPH 4h STRATIOMYIDAE 1967



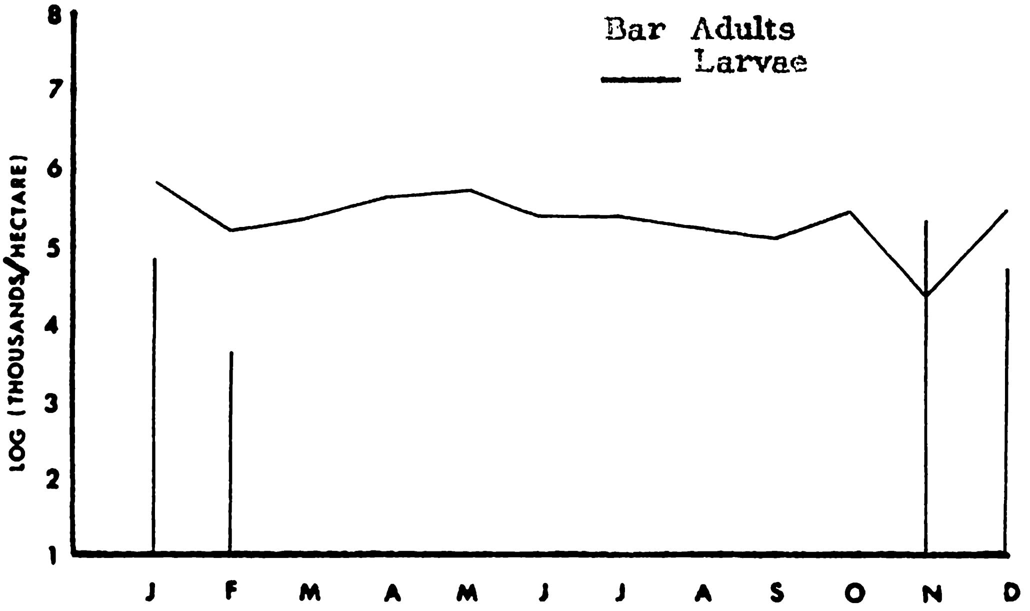
GRAPH 4i CARABIDAE 1967



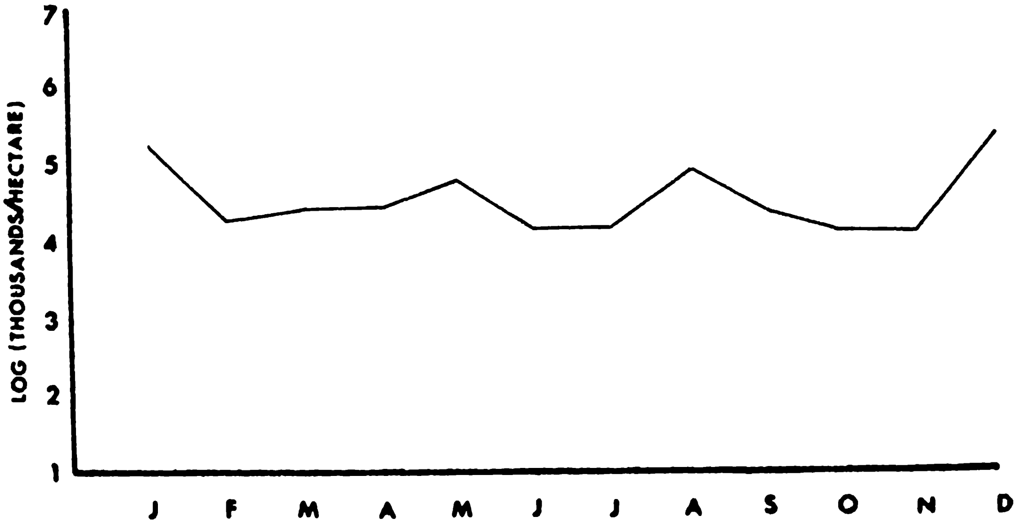
GRAPH 4j STAPHYLINIDAE 1967



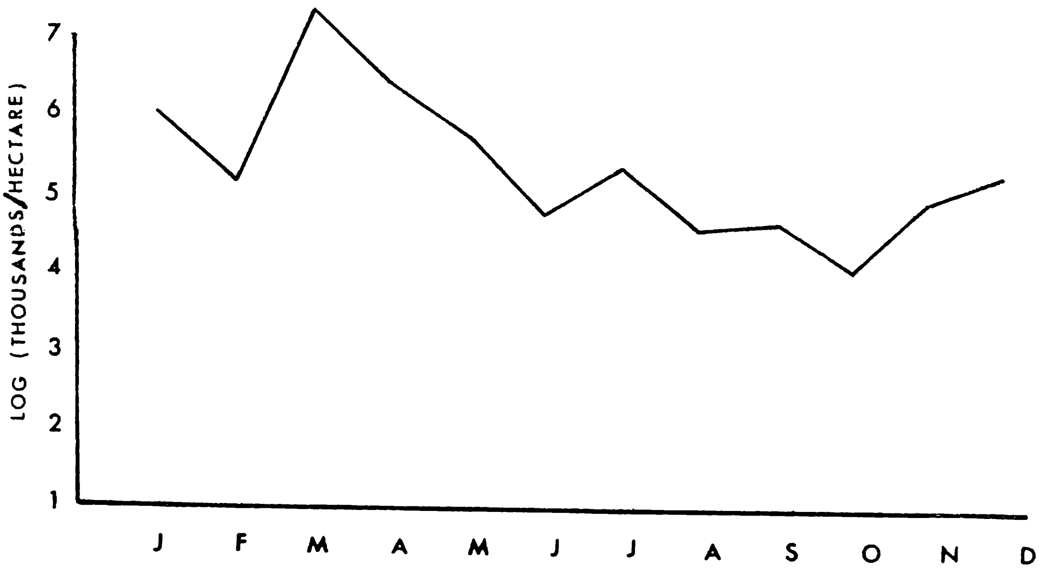
GRAPH 4 k SCARABIDAE 1967



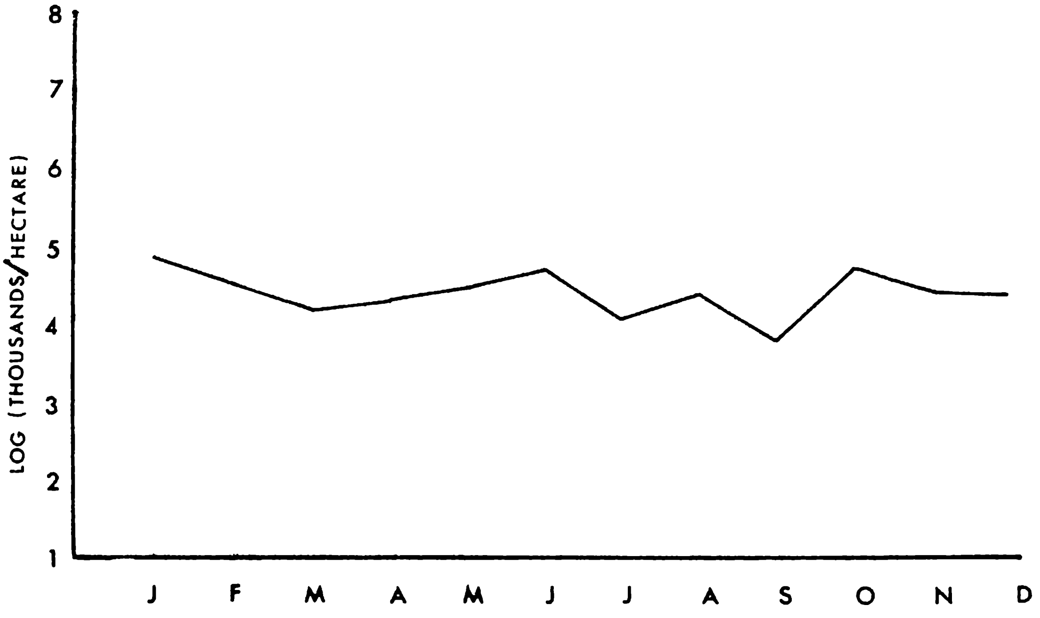
GRAPH 41 ELATERIDAE 1967



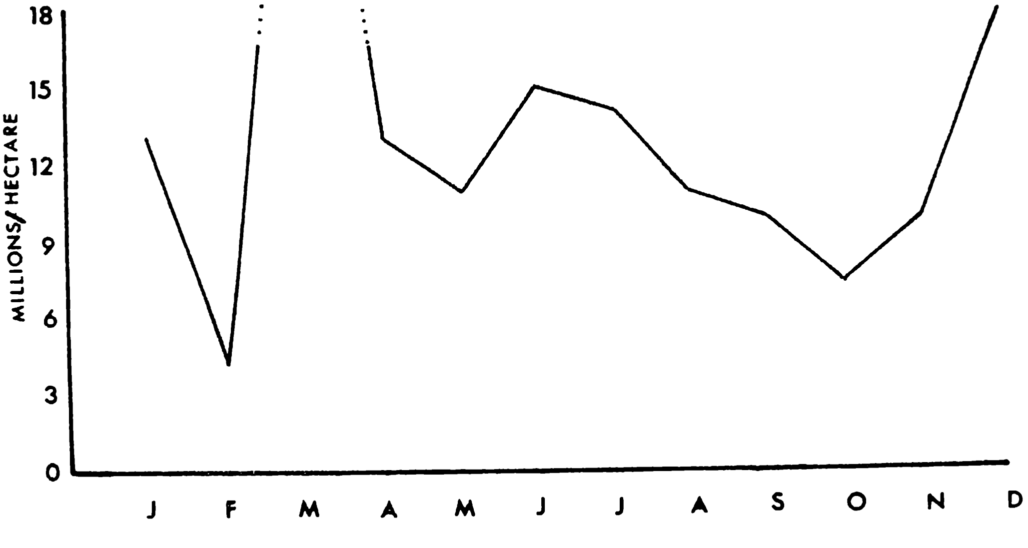
GRAPH 4m COLLEMBOLA 1967



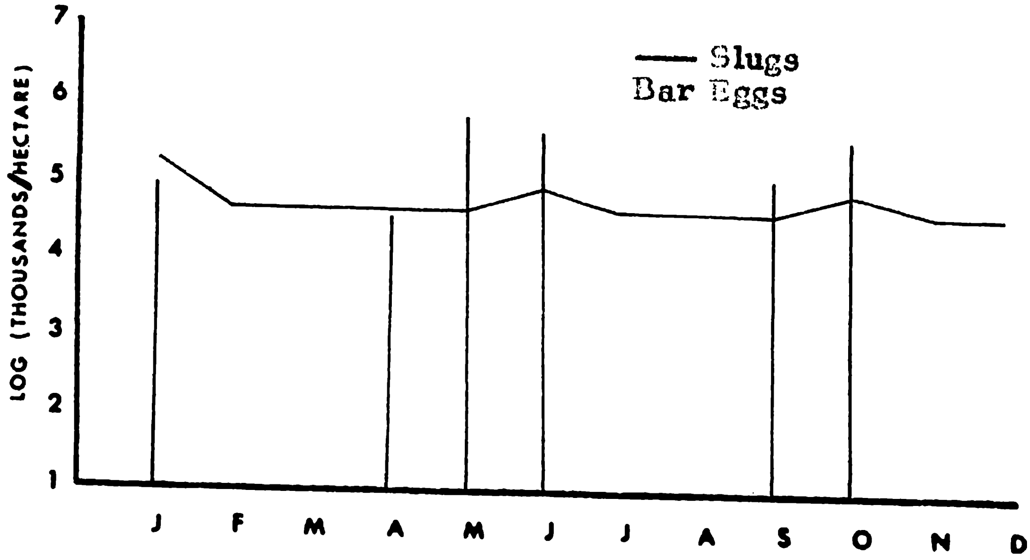
GRAPH 4n OTHER GROUPS 1967



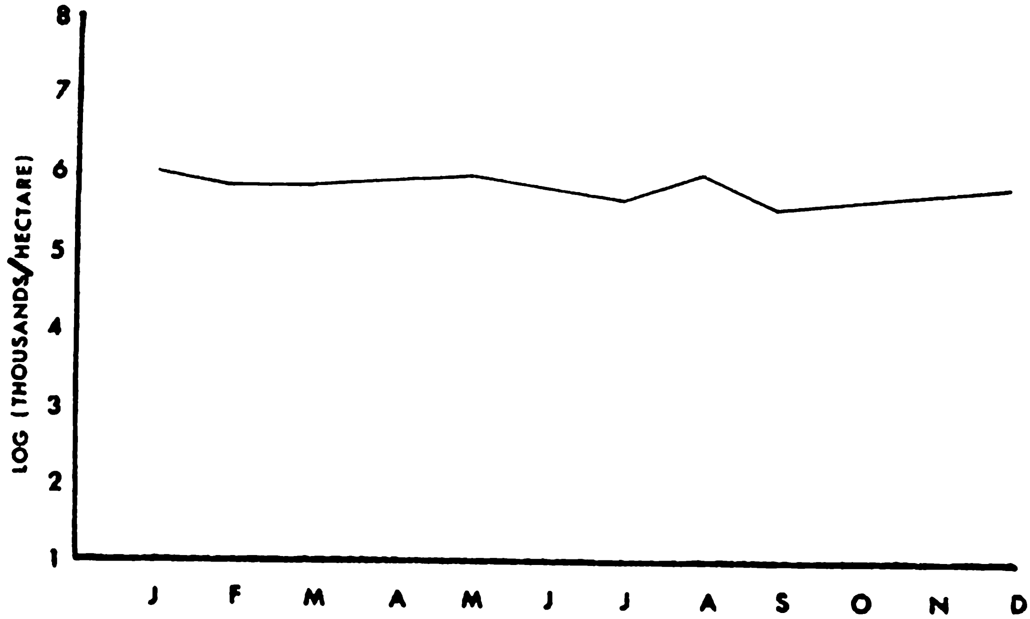
GRAPH 4o TOTAL FAUNA 1967



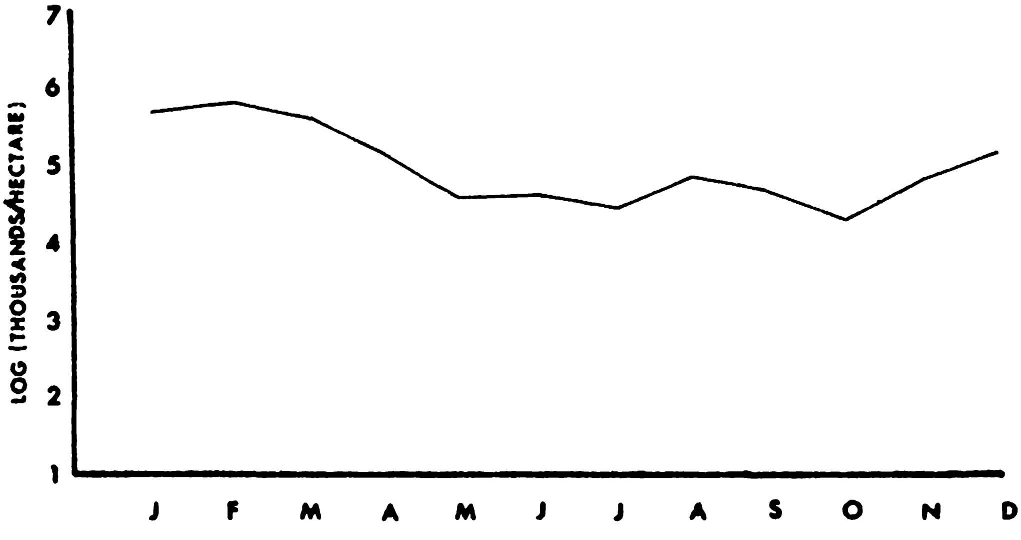
GRAPH 5a MOLLUSCA 1968



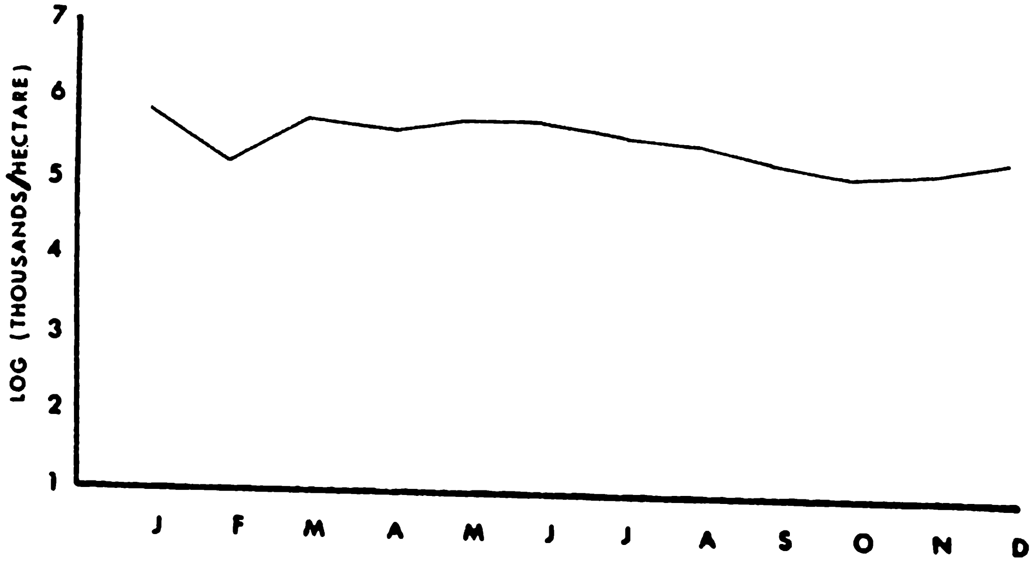
GRAPH 5b ACARINA 1968



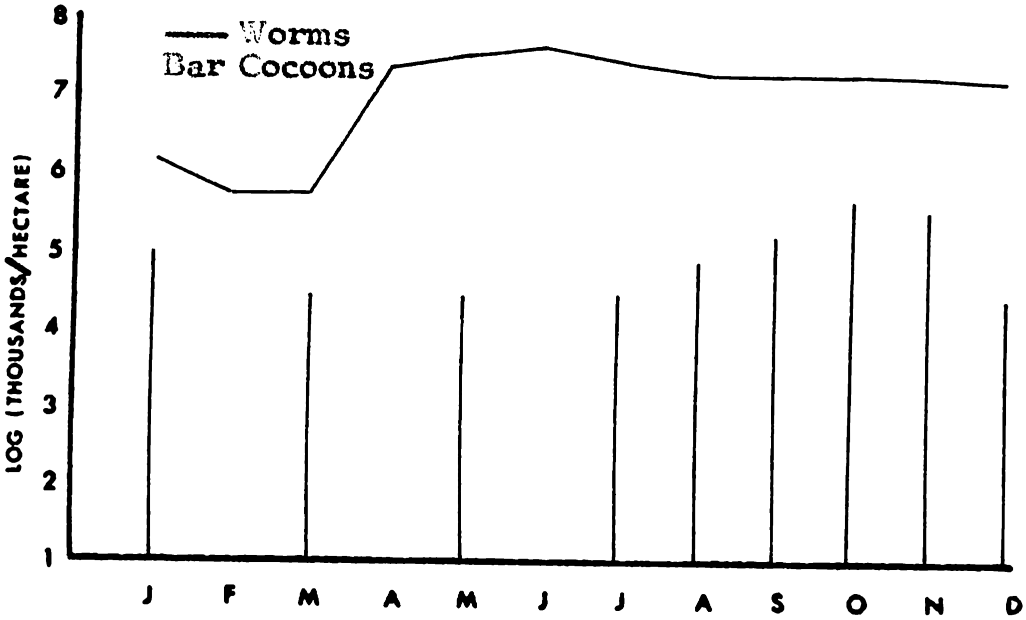
GRAPH 5c ARANEIDA 1968



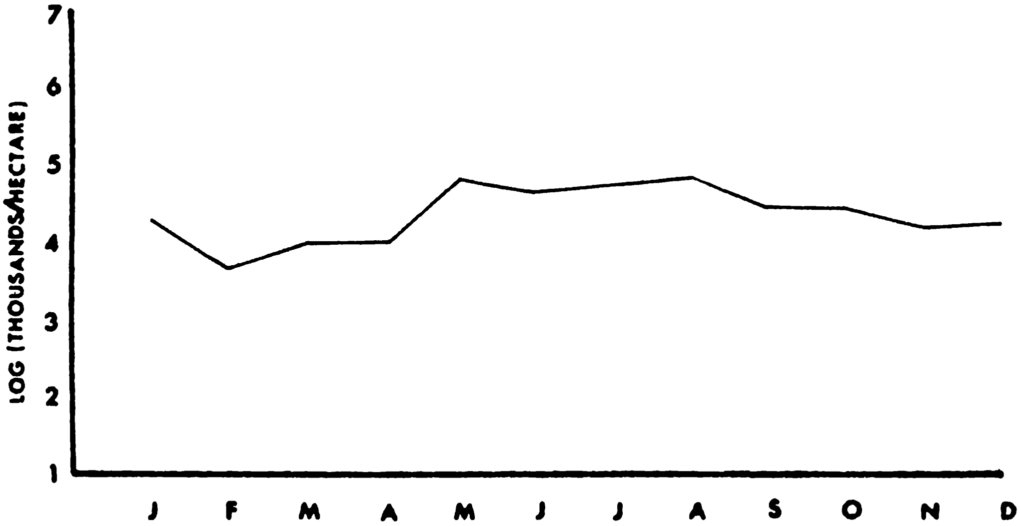
GRAPH 5d CHILOPODA 1968



GRAPH 5e LUMBRICIDS 1968

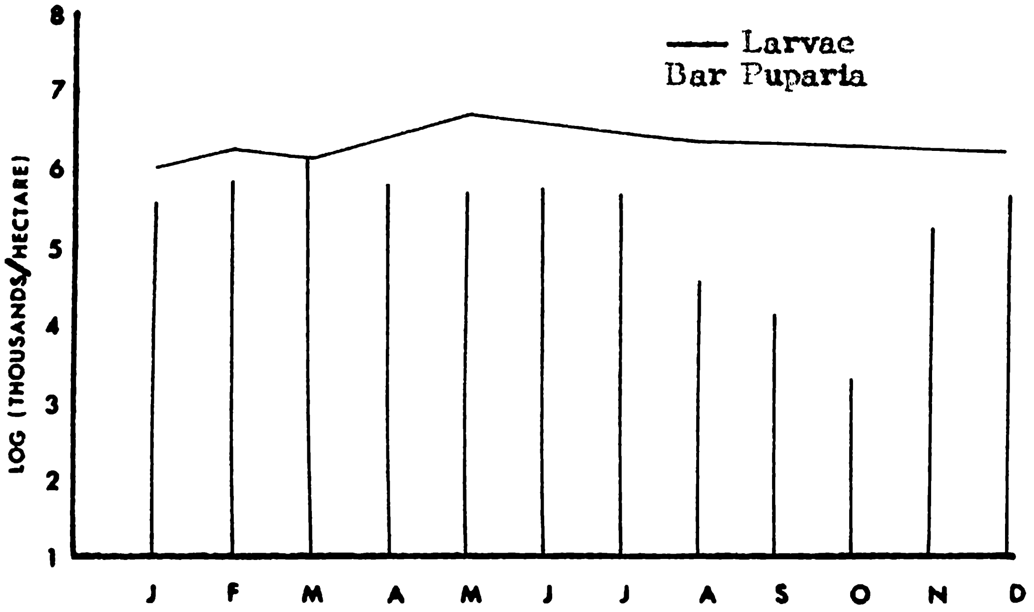


GRAPH 5f ENCHYTRAEIDS 1968

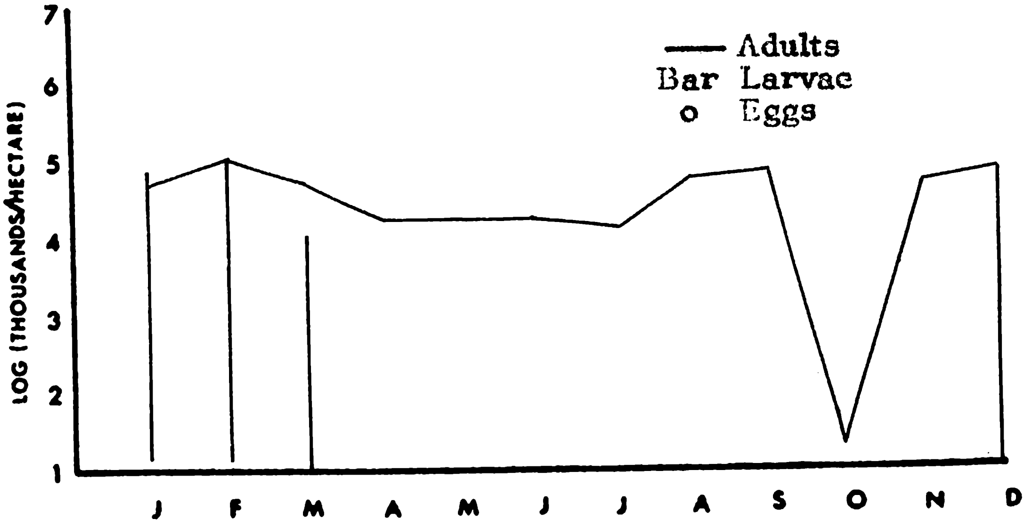


GRAPH 5g **FORMICIDAE** 1968

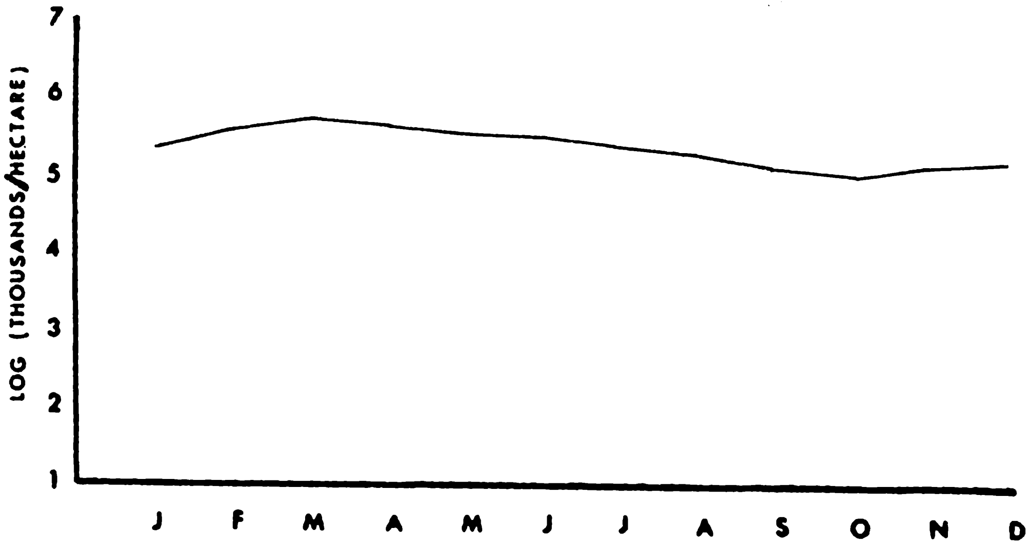
GRAPH 5h **STRATIOMYIDAE** 1968



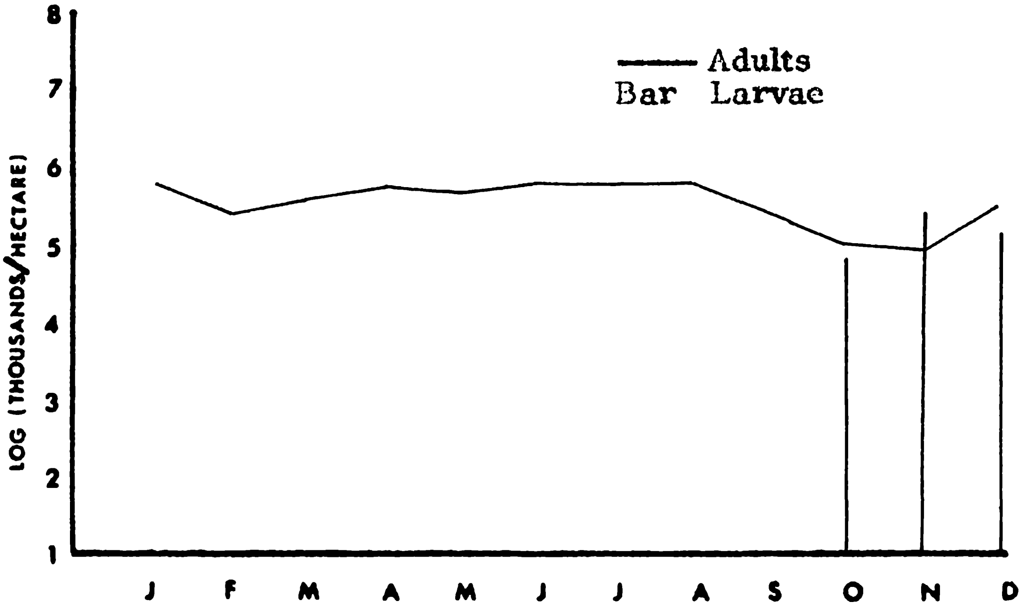
GRAPH 5i **CARABIDAE** 1968



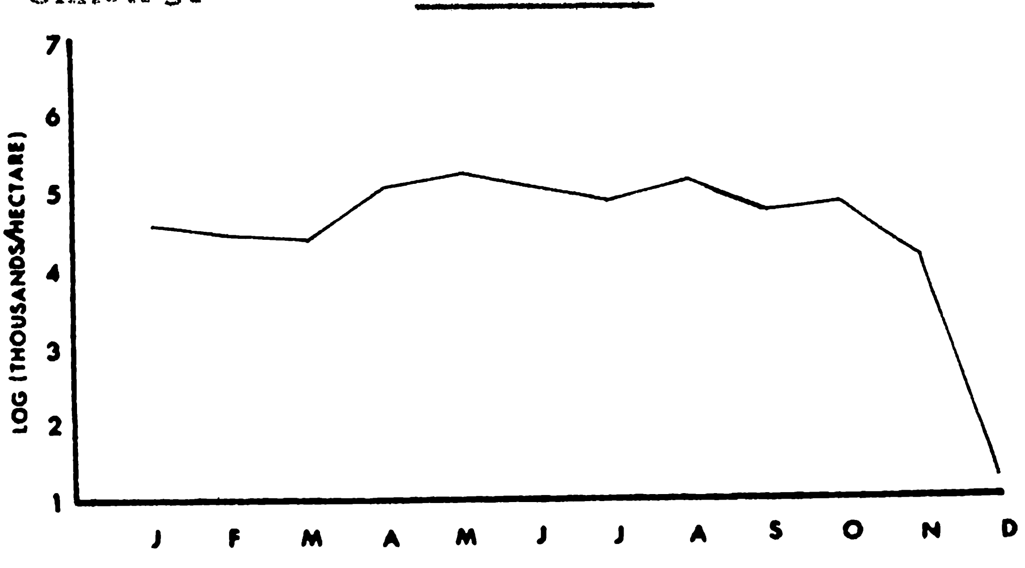
GRAPH 5j STAPHYLINIDAE 1968



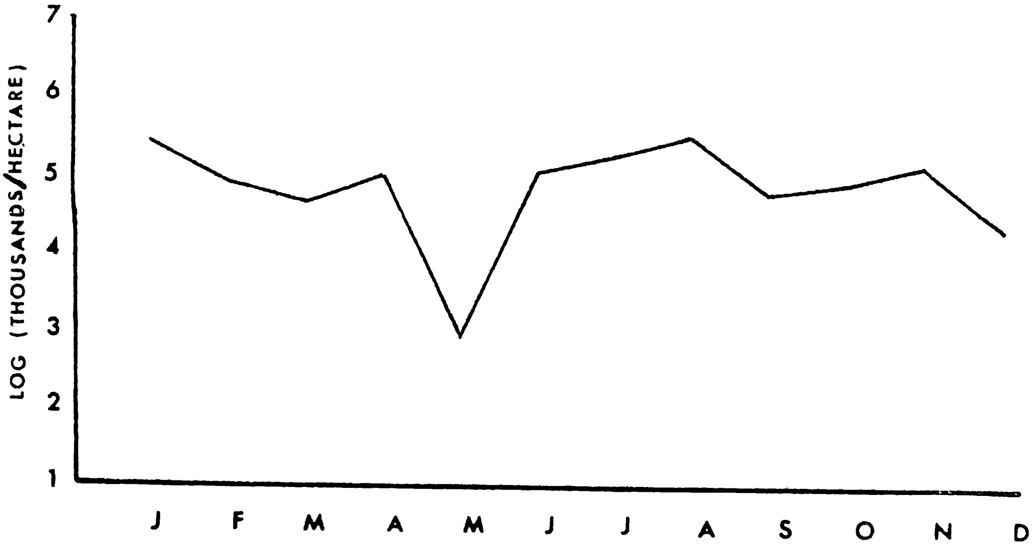
GRAPH 5k SCARABIDAE 1968



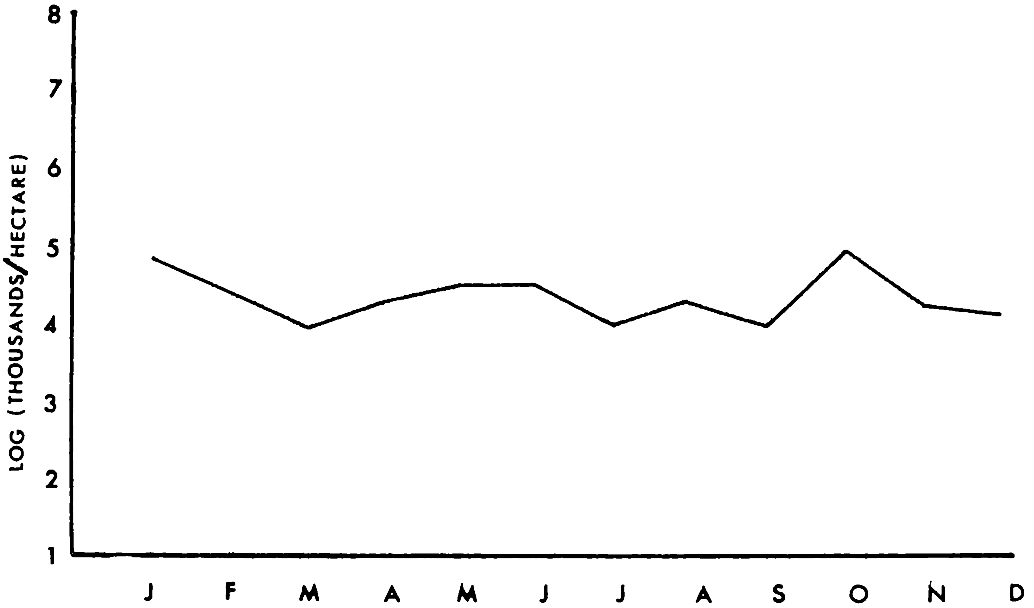
GRAPH 5l ELATERIDAE 1968



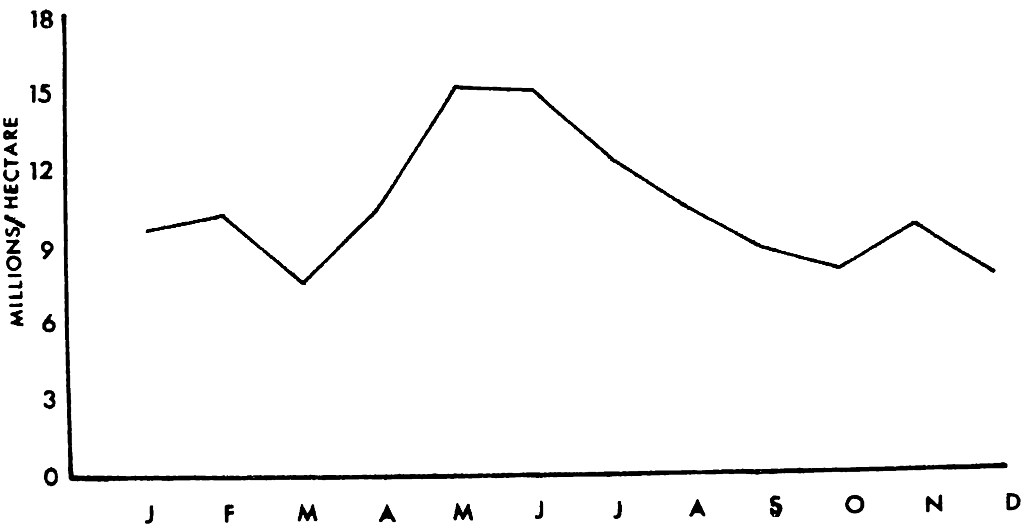
GRAPH 5m **COLLEMBOLA** 1968



GRAPH 5n **OTHER GROUPS** 1968

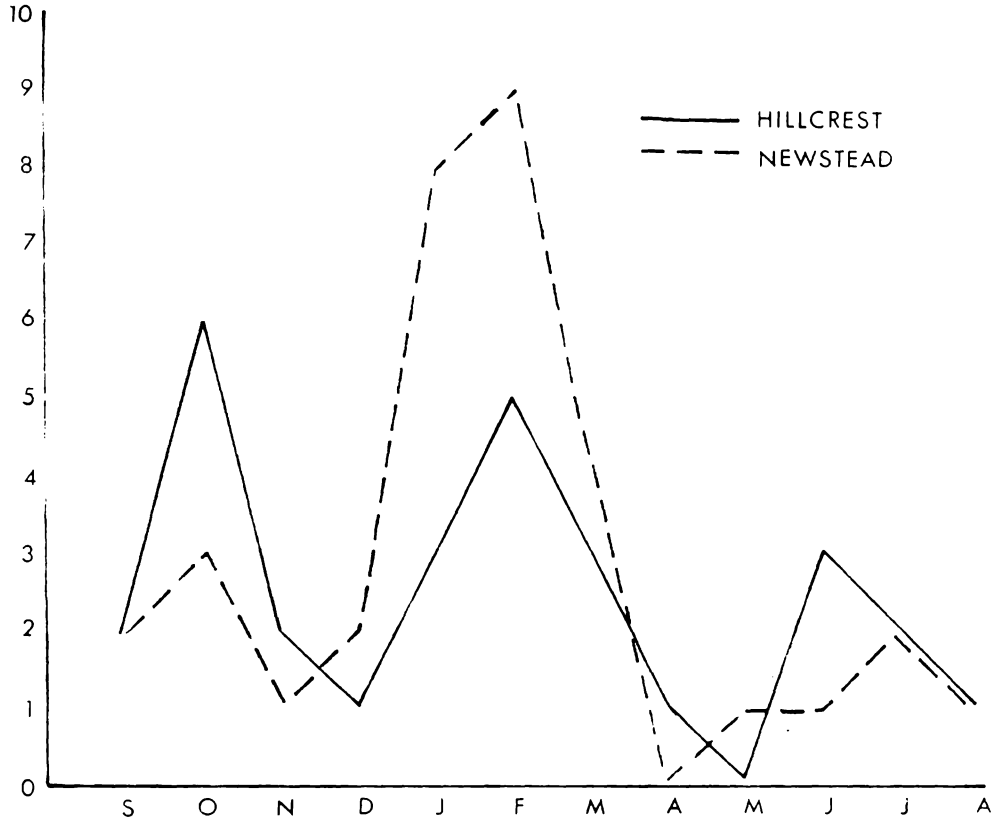


GRAPH 5o **TOTAL FAUNA** 1968



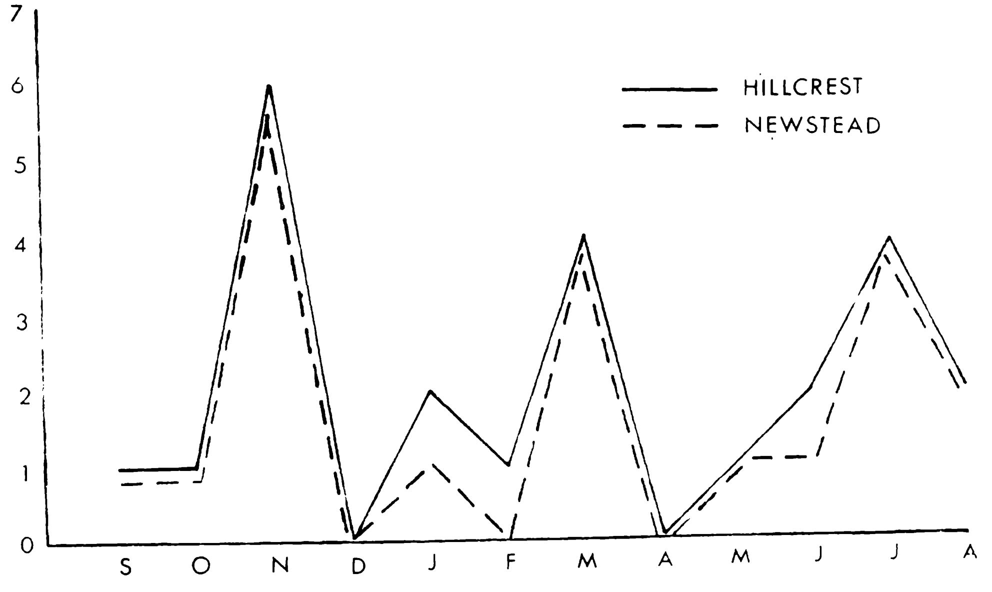
FAUNA 1970-71

GRAPH 6a NUMBERS OF GROUPS AT MINIMUM POPULATION LEVEL



FAUNA 1970-71

GRAPH 6b NUMBERS OF GROUPS AT MAXIMUM POPULATION LEVEL



SECTION 7 : VERTICAL DISTRIBUTION

(a) Introduction

Soil-dwelling animals undertaking vertical migrations (depending on temperature, humidity and aeration of the soil) introduce into the soil organic matter of plant origin. When digging passageways and bringing soil from deep layers to the surface, they contribute to the mixing of different soil layers. By burrowing, soil-dwelling animals create soil channels, ensure the infiltration of rainfall into the soil, thus introducing organic remnants from the surface. By clearing the dead roots and litter away, even very small microarthropods help to increase the number of vertical soil spaces (Jacot, 1936). By mixing mineral particles of soil with undigested remains of food processed by micro-organisms, a number of soil-dwelling invertebrates contribute to the formation of granular soil structure, which ensures a better water permeability and aeration of the soil. The total activity of soil-dwelling animals contributes to the development of an accumulative soil layer and is a potent factor in soil formation.

The depth of the activity of the whole complex of soil organisms depends in each particular area on the broad climatic conditions determined by latitude and altitude, on microclimate connected with the character of the immediate surroundings, phytoclimate linked with the type of vegetation, and by the faunal complexity of the soil organisms present.

Ghilarov (1968) mentions some relationships between the vertical distribution of humus, root systems and invertebrates in the soil. For example, the layers of soil rich in humus are rich in both roots and invertebrates, and are concentrated in the upper soil horizon. In this layer, surface plant remnants are introduced into the soil, and debris decomposition and humification occurs. The lower border of the humus horizon broadly coincides with (a) the depth of the main mass of roots, (b) the lower limit of the majority of invertebrates, and (c) with the lower border of the well-aerated layer. The spreading of roots in the soil depends largely upon the depth of the humus horizon. The depth of penetration of roots into the soil depends on the digging activity of animals. The vertical distribution of soil animals is determined, in its turn, by the depth of root penetration and by the thickness of the humus horizon. Consequently, all links - humus, roots and invertebrates - are interrelated and reciprocally determined.

Jacot (1936) states that during the periods when the soil is saturated with water, the activity of soil-dwelling invertebrates is impaired due to oxygen deficiency. During such periods, the processes of decomposition and mineralization of plant matter are carried out on the soil surface, in the litter, where the soil-dwelling invertebrates become concentrated. After the soil becomes drier and aeration more effective, during spring and early autumn particularly, the processes of decomposition of the organic mass increase in their rate of break-down, move deeper into the top soil, and there the decomposition products are released.

In summary, increase in the population density of soil invertebrates increases the depth of the soil horizon. The relationships between the character of the soil profile, environmental conditions, and the population density and vertical distribution of soil animals can be illustrated by comparing data on complexes of soil-dwelling invertebrates in similar soil types under differing amounts of vegetation.

(b) The Total Fauna

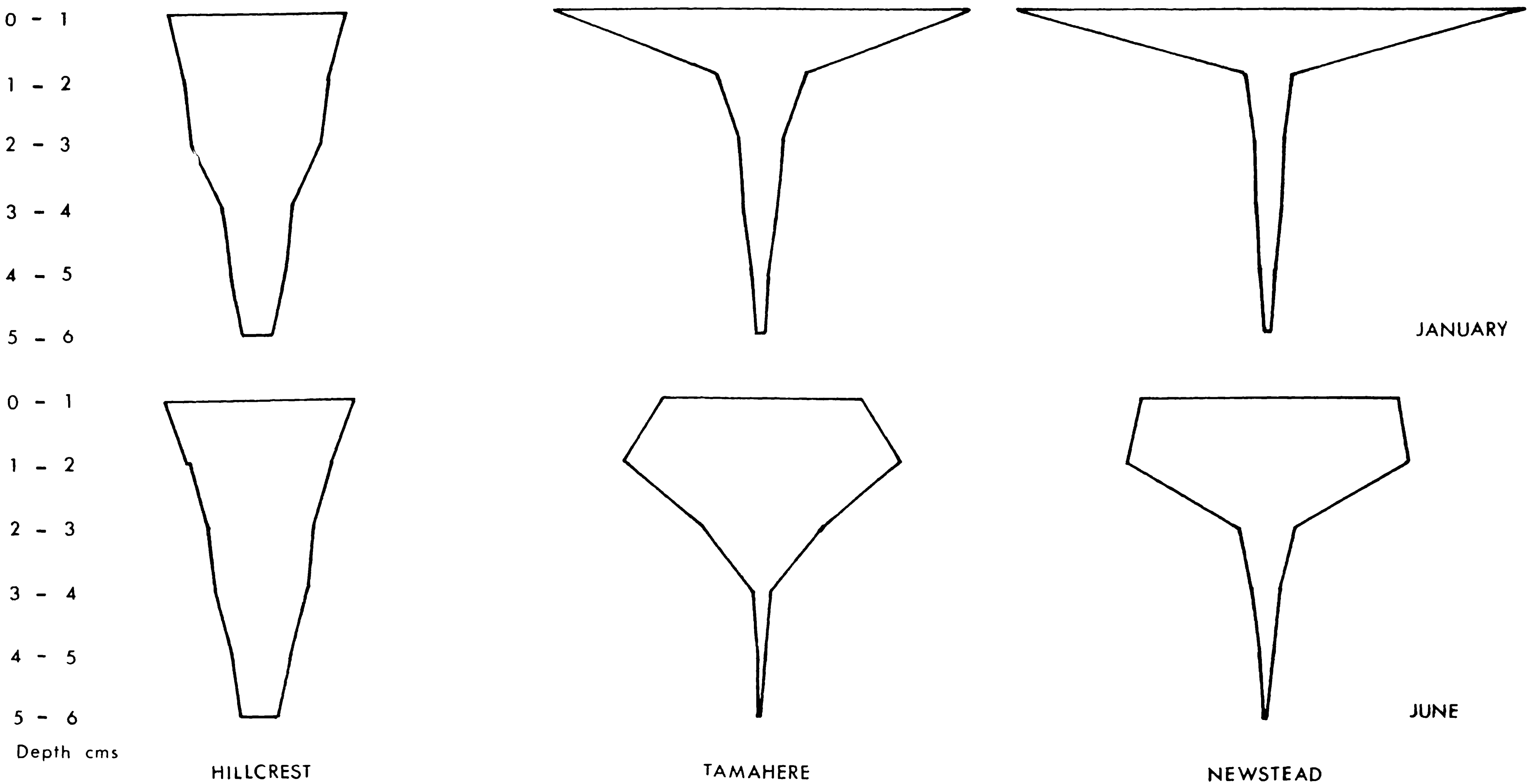
As has been demonstrated in Section 6 : Seasonal Fluctuations, there are two periods during the annual cycle when the numbers of soil-dwelling invertebrates fluctuate away from the mean. These are during the summer period, particularly in January when temperatures are consistently high and moisture in the top soil is minimal, and in June when the lower temperatures of the air, interface and soil have reduced the amount of litter being produced and the activities of the soil animals.

The author has compared the vertical distribution of some of the major faunal groups in the top soil at Hillcrest, Newstead and Tamahere during January and June. Results of the surveys are tabulated and summarised in page , and Tables 9 a, b, c. It is worth noting here that the only major difference between the three sites is that Hillcrest has a permanent and deep vegetation and litter cover. This has been removed regularly at the other two sites.

In late January, 1971, 20 samples were taken at each site, each sample to 91.5 cm depth. It was established that 94.8% of all fauna occurred within the top 6 cm of soil, except for Hillcrest where the figure was 96.2%. Research on the subsequent vertical distribution of fauna was concentrated upon the top 6 cm of soil. A sampling programme similar to the January set was carried out in June of 1971.

GRAPH 7

VERTICAL DISTRIBUTION OF FAUNA – PERCENTAGE BY DEPTH – 1972



SCALE 1mm width = 1% of total fauna at sampling time for each area

TABLE 9a

VERTICAL DISTRIBUTION - HILLCREST - 1972 PERCENTAGE OF TOTAL FOR EACH GROUP

5-6	4-5	3-4	2-3	1-2	0-1	Depth cm	
. 3.54	7.14 10.56	7.14 15.78	42.86 19.28	14.29 8.77	28.57 42.07	Jan) Jn)	Nematoda
10.00 8.30	. 8.30	30.00 8.30	. 16.73	. 58.37	60.00 .	Jan) Jn)	Lumbricids
. .	. .	. .	. .	. .	. 100.00	Jan) Jn)	Lumbricid cocoons
. 5.80	. 13.04	12.50 12.32	12.50 14.49	37.50 16.67	37.50 37.68	Jan) Jn)	Enchytracids
. .	. .	. .	. .	. .	. 100.00	Jan) Jn)	Agriolimax
. .	. .	. .	. .	. .	100.00 100.00	Jan) Jn)	Thalassohelix
. 1.86	. 7.40	. 12.96	. 9.28	55.56 11.12	44.44 57.38	Jan) Jn)	Mesostigmatids
. .	. 9.52	4.76 10.48	19.05 11.43	28.57 17.14	47.62 51.43	Jan) Jn)	Oribatids
. .	. .	. .	50.00 .	. .	50.00 100.00	Jan) Jn)	Arachnida
23.08 2.86	7.69 5.71	7.69 14.29	7.69 17.14	30.77 22.86	23.08 37.14	Jan) Jn)	Geophilus
. .	. .	. .	44.44 2.27	11.12 6.85	44.44 90.88	Jan) Jn)	Orchestia
. 18.18	20.00 36.36	50.00 27.28	20.00 9.09	10.00 9.09	. .	Jan) Jn)	Symphyla

VERTICAL DISTRIBUTION - HILLCREST - 1972 PERCENTAGE OF TOTAL FOR EACH GROUP

TABLE 9a. (continued)

5-6	4-5	3-4	2-3	1-2	0-1	Depth cm	
•	•	•	•	33.33	66.67	Jan)	Collembola
11.05	13.95	15.98	16.50	19.22	23.30	Jn)	
7.69	13.74	12.64	25.27	22.53	18.13	Jan)	Altermetaponia
2.47	6.23	13.64	21.64	32.55	23.45	Jn)	larvae
•	•	7.14	7.14	28.58	57.14	Jan)	Altermetaponia
•	•	•	•	9.09	90.91	Jn)	puparia
•	•	•	•	•	•	Jan)	Tipulid
5.82	4.65	22.10	19.77	25.56	22.10	Jn)	larvae
•	•	•	•	•	100.00	Jan)	Creophilus
•	•	16.67	16.67	•	66.66	Jn)	
•	•	•	•	•	100.00	Jan)	Carabidae
•	•	•	•	•	100.00	Jn)	
•	•	•	•	•	•	Jan)	Carabid
•	•	•	•	•	100.00	Jn)	larvae
•	•	•	•	•	•	Jan)	Wiseana
•	•	•	50.00	•	50.00	Jn)	larvae
•	•	•	•	50.00	50.00	Jan)	Formicidae
41.65	•	8.33	16.66	33.36	•	Jn)	
•	•	•	•	•	100.00	Jan)	Chalcidae
•	•	•	•	•	•	Jn)	
•	•	•	•	•	100.00	Jan)	Aphid
•	•	•	•	25.00	75.00	Jn)	nymphs
5.83	9.38	11.00	22.65	22.98	28.16	Jan)	% by depth
5.93	9.92	14.17	17.05	22.58	30.35	Jn)	

TABLE 9b

VERTICAL DISTRIBUTION - NEWSTEAD - 1972 PERCENTAGE OF TOTAL FOR EACH GROUP

5-6	4-5	3-4	2-3	1-2	0-1	Depth cm	
• 5.56	11.12 5.56	33.33 16.66	33.33 33.33	22.22 38.89	• •	Jan) Jn)	Nematoda
• •	• •	• •	• 40.00	• 60.00	• •	Jan) Jn)	Lumbricids
• •	• •	• •	• •	• •	• •	Jan) Jn)	Lumbricid cocoons
• 8.33	16.67 8.33	• 16.67	33.33 25.00	33.33 33.33	16.67 8.34	Jan) Jn)	Enchytraeids
• •	• •	• •	• •	• •	• •	Jan) Jn)	Agriolimax
• •	• •	• •	• •	• •	• •	Jan) Jn)	Agriolimax eggs
• •	• •	• •	• •	• •	• •	Jan) Jn)	Thallasohelix
• 1.54	• 3.07	• 9.23	• 21.54	16.67 46.16	83.33 18.46	Jan) Jn)	Mesostigmatids
• •	• 2.06	2.00 3.09	3.00 8.26	6.00 14.43	89.00 72.16	Jan) Jn)	Oribatids
• •	• •	• •	• •	50.00 •	50.00 •	Jan) Jn)	Arachnida
• •	• 14.29	50.00 14.29	50.00 28.57	• 42.85	• •	Jan) Jn)	Geophilus
• •	• •	• •	4.64 33.33	42.24 66.67	58.12 •	Jan) Jn)	Orchestia

TABLE 9b (continued)

5-6	4-5	3-4	2-3	1-2	0-1	Depth cm
• 16.67	• 16.67	60.00 33.33	40.00 33.33	• •	• •	Jan) Jn) Symphyla
• •	0.40 •	4.51 1.16	2.05 4.06	5.74 52.75	87.30 42.03	Jan) Jn) Collembola
9.09 7.14	27.27 7.14	18.19 14.29	27.27 14.29	9.09 35.71	9.09 21.43	Jan) Altermetaponia Jn) larvae
• •	• •	• •	• •	• 37.50	• 62.50	Jan) Altermetaponia Jn) puparia
• •	• •	• •	• •	• •	• •	Jan) Tipulid Jn) larvae
• •	33.33 •	• •	• •	• 66.67	66.67 33.33	Jan) Jn) Creophilus
• •	• •	• •	• •	• •	100.00 100.00	Jan) Jn) Carabidae
• •	• •	• •	• •	• •	• •	Jan) Caribid Jn) larvae
• •	• •	• •	• •	• •	• •	Jan) Wiseana Jn) larvae
10.00 15.39	10.00 7.69	20.00 15.39	20.00 23.07	10.00 30.77	30.00 7.69	Jan) Jn) Formicidae
• •	• •	• •	• •	• •	100.00 •	Jan) Jn) Chalcidae
• •	• •	• •	• •	• •	• •	Jan) Aphid Jn) nymphs
0.47 1.16	1.89 1.66	5.66 4.15	4.95 9.62	7.55 43.45	79.48 39.96	Jan) Jn) % by depth

VERTICAL DISTRIBUTION - NEWSTEAD - 1972 PERCENTAGE OF TOTAL FOR EACH GROUP

TABLE 9c

VERTICAL DISTRIBUTION - TAMAHERE - 1972 PERCENTAGE OF TOTAL FOR EACH GROUP

5-6	4-5	3-4	2-3	1-2	0-1	Depth cm	
• 3.13	4.55 6.25	31.82 9.37	40.91 43.75	13.63 28.13	9.09 9.37	Jan) Jn)	Nematoda
33.33 •	• 25.00	33.33 25.00	33.34 50.00	• •	• •	Jan) Jn)	Lumbricids
• •	• •	50.00 •	50.00 •	• •	• •	Jan) Jn)	Lumbricid cocoons
6.90 2.86	6.90 5.71	20.69 28.57	37.92 51.43	20.69 11.43	6.90 •	Jan) Jn)	Enchytraeids
• •	• •	• •	• •	• •	• •	Jan) Jn)	Agriolimax
• •	• •	• •	• •	• •	100.00 •	Jan) Jn)	Thallasohelix
13.64 5.56	9.09 2.78	• 5.56	4.54 8.33	9.09 50.00	63.64 27.77	Jan) Jn)	Mesostigmatids
3.10 1.33	9.65 0.67	8.28 2.00	8.97 5.33	6.55 10.67	63.45 80.00	Jan) Jn)	Oribatids
• •	• •	• •	• •	• •	100.00 100.00	Jan) Jn)	Arachnida
• •	• •	• •	• 28.57	• 57.14	• 14.29	Jan) Jn)	Geophilus
• •	12.50 •	12.50 •	37.50 •	25.00 •	12.50 •	Jan) Jn)	Orchestia
50.00 20.00	• 10.00	• 40.00	• 20.00	50.00 10.00	• •	Jan) Jn)	Symphyla

TABLE 9 c (continued)

VERTICAL DISTRIBUTION - TAMAHERE - 1972 PERCENTAGE OF TOTAL FOR EACH GROUP

5-6	4-5	3-4	2-3	1-2	0-1	Depth cm	
0.44	0.77	2.20	4.40	11.88	80.31	Jan)	Collembola
.	0.30	1.40	18.00	50.20	30.10	Jn)	
12.04	8.90	15.18	10.99	36.13	16.76	Jan)	Altermetaporia
0.61	3.05	10.37	26.22	51.22	8.53	Jn)	larvae
.	.	.	9.09	.	90.91	Jan)	Altermetaporia
.	.	.	.	25.00	75.00	Jn)	puparia
.	.	.	.	.	.	Jan)	Tipulid
.	.	.	.	.	.	Jn)	larvae
.	.	.	50.00	.	50.00	Jan)	Creophilus
.	.	.	25.00	25.00	50.00	Jn)	
.	.	.	.	.	.	Jan)	Carabidae
.	.	.	.	33.33	66.67	Jn)	
.	.	.	.	.	.	Jan)	Carabid
.	.	.	.	.	.	Jn)	larvae
.	.	.	.	.	.	Jan)	Wiseana
.	.	.	.	.	.	Jn)	larvae
16.68	.	16.68	25.00	8.30	33.34	Jan)	Formicidae
18.18	9.09	18.18	18.18	9.09	27.28	Jn)	
.	.	.	.	.	100.00	Jan)	Chalcidae
.	.	.	.	.	.	Jn)	
.	.	.	.	.	100.00	Jan)	Aphid
.	.	.	.	.	.	Jn)	nymphs
2.99	3.85	6.11	7.77	14.01	65.27	Jan)	% by depth
0.74	1.23	3.92	18.81	43.78	31.52	Jn)	

PERCENTAGE FAUNA PRESENT AT EACH LEVEL

	Hillcrest		Newstead		Tamahere	
cm	January	June	January	June	January	June
0-1	28.16	30.35	79.48	39.96	65.27	31.52
0-2	22.98	22.58	7.55	43.45	14.01	43.78
2-3	22.65	17.05	4.95	9.62	7.77	3.92
3-4	11.00	14.17	5.66	4.15	6.11	3.92
4-5	9.38	9.92	1.89	1.66	3.85	1.23
5-6	5.83	5.93	0.47	1.16	2.99	0.74

From the above table, the following conclusions can be made :

1. When the January and June figures for Hillcrest are compared it can be seen that little change occurs in the vertical distribution of fauna. The main changes which do occur, however, are a 2.84% increase in fauna in the top 1 cm level and slight increase in the 3-6 cm layers, but these are of low percentage, being 3.17%, 0.54% and 0.10% respectively. However, a decrease of 5.60% occurs in the 2-3 cm level.

2. At Newstead, when January and June figures are compared, a marked change can be observed. The top 1 cm of the soil has reduced its faunal total by 40.75%, and the 2-3 cm and 3-4 cm levels have increased the faunal totals by 35.90% and 4.67% respectively. The lower levels (4-6 cm)show only small changes, i.e., -1.51%, -0.23% and +0.60% respectively.

3. At Tamahere, a change similar to that of Newstead but different from Hillcrest has occurred. The top 1 cm level has reduced its total fauna by 33.75% and the 1-2 and 2-3 cm levels have increased their totals by 29.77% and 11.04% respectively.

The changes in the 4-6 cm levels are small but slightly greater than at Newstead, i.e., -2.19%, -2.62% and -2.25%.

The difference in pH between January and June (see Table 6) is 1.49 at Hillcrest and 1.38 at Newstead.

The difference in atmospheric temperature between January and June means at Hillcrest is 8.5°C and at Newstead is 8.5°C as well. The temperature range is 25.5°C at Hillcrest in January and 20.0°C in June. At Newstead the January temperature range is 18.0°C and in June is 21.0°C.

The difference between the January and June means for interface temperatures at Hillcrest is 9.5°C and at Newstead is 10.5°C. The range of interface temperatures in January at Hillcrest is 15.0°C and June 19.0°C. At Newstead the January range is 18.0°C, reaching a greater maximum than at Hillcrest, and that of June is 21.0°C, reaching a lower minimum than at Hillcrest.

The difference in subsoil temperature between January and June at Hillcrest is 9.0°C (the January range is 8.0°C and the June range is 9.0°C), while that of Newstead is 11.0°C. January range is 10.0°C, reaching a greater maximum than Hillcrest; June range is 11.0°C, reaching a lower minimum than Hillcrest. For the Hillcrest/Newstead comparisons, see Graphs 1c, 2c.

Top soil moisture content difference between January and June at Hillcrest is 22.0% and at Newstead is 32.0%.

The only major difference between the two sites is that Hillcrest retains a well-developed vegetation and litter cover during the year.

The author would hypothesise that the state of the litter and vegetation is responsible for the variation in the vertical distribution of soil-dwelling invertebrates in the top soil, because the extent of fluctuation of interface and soil temperatures, as well as summer top soil moisture content, is closely related to the height of vegetation and depth of litter.

(c) Lumbricidae

At Hillcrest in January, 60% of earthworms are in the 0-1 cm level and distributed irregularly in depth. In June, 58% are in the 1-2 cm level - distribution is even but decreasing in numbers with depth. Cocoons are produced in June in the top 0-1 cm level, but are absent in January samples.

Both Newstead and Tamahere show an absence of earthworms in the top 2 cm of soil in January, but are present below the 2 cm level at Tamahere, although in small numbers. They did not occur in January samples at Newstead. In June, the numbers of earthworms at Newstead and Tamahere increase. 60% are in the 1-2 cm level at Newstead and 50% in the 2-3 cm level at Tamahere.

(d) Enchytraeidae

In January at Hillcrest, enchytraeids occur within the top 4 cm of soil (75% within the top 2 cm), while in June they are distributed through the 6 cm depth, decreasing in numbers with increasing depth.

At Newstead in January, 67% are found in the 1-3 cm level, but in June the distribution is more uniform, decreasing in numbers with depth, but the majority are in the 1-3 cm level (58%).

At Tamahere in January, the distribution is more regular than at Newstead, but the majority are in the 2-4 cm level (79%). During

June, the distribution tends to concentrate more in the 2-4 cm level (91%), with a diminution of numbers at levels below 4 cm.

(e) Mollusca

Agriolimax reticulatus is absent from all three sites in January, but is present at Hillcrest in the 0-1 cm level in June - absent at the other two sites in June. Thallasohelix is present at Tamahere and Newstead in January in the 0-1 cm level, but present in June at Hillcrest only and in the same depth. In each case the numbers of individuals is very small. No eggs have been observed at either period at any of the three sites.

(f) Crustacea

At Hillcrest in January, Orchestia is present in the top 1 cm level (44%) and present down to 3 cm, 44% being present at the 2-3 cm level. In June, however, the 0-1 cm level has 91% of individuals present, although distribution is still no further than 3 cm in depth.

At Newstead in January, the total numbers present are less than at Hillcrest, and penetration of the soil occurs to 3 cm. The greatest number is in the 0-1 cm level. In June the numbers present increased, penetration is to the same depth but 67% occur at the 1-2 cm level.

At Tamahere in January, Orchestia occur down to the 5 cm level, with 58% at the 1-3 cm level. No specimens have been recovered during the June sampling.

(g) Myriapoda

In January at Hillcrest, myriapods attain their maximum numbers at the 1-2 cm level (31%), but 23% are in the 0-1 cm level. In June, 37% are in the top 1 cm and numbers decrease progressively and steadily down to the 6 cm level.

At Newstead in January, there are no myriapods in the top 2 cm. All specimens have been recorded at 2-4 cm depth. In June, 43% are in the 1-2 cm level and decrease steadily down to 5 cm.

In January at Tamahere, no myriapods have been recorded at any level, but in June, 57% are in the 1-2 cm level; 29% in the 2-3 cm level, and the remainder (14%) in the top 1 cm of the soil.

(h) Arachnida

Hillcrest in January, has 50% of the Arachnida in the top 1 cm and in June, 100% at the same level.

Newstead has 50% in the top 1 cm in January, but Arachnida have not been collected in June.

Tamahere has all Arachnida in the top 1 cm both in January and in June.

(i) Acarina

In January at Hillcrest, mesostigmatid mites are concentrated in the top 2 cm, with 56% in the 1-2 cm level. Oribatids occur in the top 4 cm, with the greatest numbers (48%) occurring in the 0-1 cm level.

In June, mesostigmatids extend to the full depth of 6 cm, with the greatest numbers (57%) occurring at the 0-1 cm level. Oribatids occur down to the 5 cm level, with the greatest numbers (51%) at the 0-1 cm level.

In January at Newstead, mesostigmatid mites are present in the top 2 cm of soil, with the greatest concentrations of population

(83%) occurring in the 0-1 cm level. Oribatids occur down to 4 cm, but with 89% at the 0-1 cm level.

In June, the mesostigmatids in the top 1 cm are reduced to 18%, increasing to 46% in the 1-2 cm level, and continuing down to 6 cm in progressively smaller numbers. The oribatids extend their range down to 5 cm and although still numerous in the 0-1 cm level, are reduced to 72% of the total number present.

At Tamahere in January, mesostigmatids occur at all levels, but the greatest numbers (63%) are in the 0-1 cm level. Oribatids occur similarly, with 63% in the 0-1 cm level. In June, mesostigmatids are still present at all levels, but the greatest population (50%) occurs at the 1-2 cm level. The top 1 cm is reduced to 28% of the population. Oribatids in June occur at all levels but 80% occur in the 0-1 cm level; the remainder occur in progressively decreasing numbers as the depth of soil increases.

(j) Collembola

67% occur in the top 1 cm at Hillcrest in January. The remainder are found in the 1-2 cm level. In June, distribution occurs throughout the 6 cm of soil, with the greatest numbers (23%) occurring in the 0-1 cm level.

At Newstead in January, 87% of Collembola are found in the top 1 cm of soil, while the remainder occur in decreasing numbers down to the 5 cm level. In June, distribution occurs down to the 4 cm level, with the greatest numbers (53%) being in the 1-2 cm level. The top 1 cm has its population reduced to 42%.

At Tamahere in January, the greatest numbers (80%) occur in the 0-1 cm level and numbers reduce progressively down to 6 cm.

In June, the population extends to 5 cm depth, and the greatest numbers occur at the 1-2 cm level. 30% occur in the 0-1 cm level.

(k) Staphylinidae

In January at Hillcrest, all staphylinids occur in the top 1 cm of soil, but in June the population is reduced to 67% in this level; the remainder are evenly distributed down to 4 cm.

At Newstead in January, 67% are in the top 1 cm, but this is reduced to 33% in June, with the remaining 67% occurring in the 1-2 cm level.

At Tamahere in January, 50% occur in the 0-1 cm level and 50% in the 2-3 cm level. In June, 50% occur in the top 1 cm still, and the remaining population is evenly distributed within the 1-3 cm level.

(l) Carabidae

In January and June, all adult carabids occur in the 0-1 cm level at Hillcrest. Larvae are absent in January but found in June, and then only in the 0-1 cm level.

At Newstead, all adults are found in the 0-1 cm level in January and June and no larvae have been recorded at either time.

No adults occur in January at Tamahere, but in June, 67% are found in the top 1 cm, and 33% in the 1-2 cm level. No larvae have been found in January or June.

(m) Chalcidae

At all three sites, chalcids are found only in January, and all specimens occur in the top 1 cm of the soil.

(n) Formicidae

At Hillcrest in January, ants are evenly distributed in the top 2 cm of the soil, but in June the majority (42%) occur in the top 1 cm with the remainder evenly distributed through and down to the 6 cm level.

At Newstead, ants are evenly distributed throughout the 6 cm of top soil in January, with 30% (the maximum number) in the 0-1 cm level. In June, distribution is uniform throughout the 6 cm, except that the 0-1 cm level is reduced to 8%, the maximum number (31%) being in the 1-2 cm level.

At Tamahere in January, distribution is uniform through the 6 cm of the soil, with the maximum (33%) in the 0-1 cm level. In June, the distribution is still uniform but the maximum in the 0-1 cm level is reduced to 27%.

(o) Diptera

Tipulid larvae occur only at Hillcrest and only in June. Distribution is even, but decreases in numbers with depth. The maximum population (26%) is in the 1-2 cm level.

Altermetaponia rubriceps is distributed uniformly through the six centimetres of soil at Hillcrest in January, with the maximum numbers (25%) occurring in the 2-3 cm level. In June, the tendency is for greater numbers to occur in the top 3 cm, and a decrease to occur in the 1-2 cm level. Puparia are present in the top 4 cm in January, with a maximum of 57% in the 0-1 cm level. In June, 90% of puparia are in this level with the remainder in the 1-2 cm level.

At Newstead in January, the majority of larvae are in the 2-3 cm and 4-5 cm levels (27% in each), whereas in June the distribution is more uniform, although numbers decrease with depth, and the maximum numbers are in the 1-2 cm level. Puparia are absent in January, while in June 63% are in the 0-1 cm level, and the remainder in the 1-2 cm level.

In January at Tamahere, larvae are evenly distributed in all levels, scarcely decreasing in numbers with increasing depth, the maximum number (36%) occurring in the 1-2 cm level. In June, the maximum numbers (51%) occur at this level, and the remainder occur to the full 6 cm level, decreasing in numbers with increasing depth. 90% of puparia occur at the 0-1 cm level in January, and in June, 75% occur at this level although the total numbers in June are greater.

(p) Other Groups

Several other groups occur in various levels at the two sampling times. Symphyla occur at each of the three sites - numbers do not vary between sampling times, and all are found in the 1-6 cm levels, never at the surface. The majority (60%) occur in the 3-4 cm level.

To the author's surprise, neither elaterid nor scarabid larvae were recovered at either sampling time from any of the three sites. Possibly the number of samples was inadequate, yet many specimens had been recovered at Hillcrest and Newstead, using similar methods and numbers of samples, in previous years, at the same part of the annual seasonal cycle. No explanation can be offered.

SUMMARY

The data presented in this section is the result of surveys carried out in January and June 1971 at Hillcrest, Newstead and Tamahere. In each case, 25 samples were taken, and after preliminary checking in January for depth at which fauna occurred, the top 6 cm were taken, divided into 1 cm layers, and the invertebrates in each layer separately extracted. Comparison between Hillcrest and Newstead was the main point of emphasis, with Tamahere being used as a check on Newstead. Atmospheric temperatures, both mean and range, are similar at the Hillcrest and Newstead sites. Interface temperatures were similar in mean, but a smaller range occurred at Hillcrest. Temperatures did not rise as high or fall as low as at Newstead in January or June. Sub-soil temperatures differed at Hillcrest in mean and range from Newstead, neither rising as high nor falling as low. Soil moisture content was similar in June at the two sites, but in January, Hillcrest top soil was 11% moister. pH rating was similar for Hillcrest and Newstead at both sampling periods.

The major difference between the Hillcrest and Newstead sites is that a vegetation and litter cover is present throughout the year at Hillcrest.

The fauna shows a greater stability in vertical distribution at Hillcrest than at Newstead. Although 79% of the fauna is found at the 0-1 cm level at Newstead in January, this consists largely of desiccation-resistant invertebrates and occurs in smaller numbers than at Hillcrest. During June, the fauna moves to deeper levels (1-3 cm) at Newstead, although 40% of the fauna remains at the 0-1 cm level. (See page

It can be deduced that a litter/vegetation cover controls the microclimate of the top soil, and hence the activities and numbers of many soil-dwelling invertebrates. Only further and more extensive sampling, however, could determine the extent of influence definitely, and attention should be given to the temperature/moisture/population number responses in specific species. Note, however, the work of Metz (1971) on Acarina; and Hale (1966) on Collembola, where direct correlation is indicated between variations in feeding and locomotory behaviour, and variations in soil moisture and soil temperature.

SECTION 8 : LONG-TERM CHANGE IN THE BIOTIC COMPOSITION AT HILLCREST

The majority of studies on pasture phenology have been concerned with single species or small groups of species over a single annual cycle. In this section, a brief account is presented on some of the longer-term changes which have occurred at the Hillcrest site over a seven-year period, with particular emphasis on the succession of forms.

Changes in the Flora (Refer to Tables 11, 12, 13, 14.)

In August 1966, Trifolium repens covered 45% of the total area. This cover was reduced rapidly to 30% in August 1968, to 7.5% in August 1970, and 2.7% by February 1972. Soft grasses such as Agrostis gigantea, Agrostis tenuis, Anthoxanthum odoratum, Lolium perenne and Poa annua changed in total cover from 43% (August 1966) to 56% (August 1968), then reduced to 46% (August 1970), and 15% in February 1972. In all probability, the initial increase in cover was a response to the removal of mowing from the area. Perennials and coarse grasses had a combined total cover of less than 10% of the area in August 1966. By August 1968 they had increased to 12%, increased to 45% in August 1970, and in February 1972 covered 74% of the total area.

The total plant species on the site in September 1966 numbered 30. By September 1968 the total was 31 - Bromus unioloides had introduced itself. By February 1970 the total number was 29. By February 1972 the total was 25, but of this total only 5 species covered individually 10% or more of the area - Achillea millefolium 12%, Agrostis tenuis 10%, Bromus unioloides 12%, Holcus lanatus 54% and Ranunculus sardous 11%. All other species present were there as a trace only or less than 10%.

By contrast, the area adjacent to the Hillcrest site had changed by no significant amount over the seven years, and retained in 1972 similar numbers of plant species with similar percentage cover by each species.

Just why this change has occurred in the Hillcrest site is difficult to ascertain. Little change occurred in pH levels during the 7 year period, no chemicals were applied to the area and no grazing or mowing occurred. A.G. Campbell, Ruakura Agricultural Research Centre, (personal communication, 1972) has suggested the possibility of germination-inhibiting external metabolites preventing the growth of Trifolium repens. No work was done on this aspect by the author, although some workers (Wallwork, 1970) have mentioned the effect of external metabolites on root growth.

This author favours competition for space as the major factor which has effected the change and produced a succession on the Hillcrest site. Holcus lanatus has a growth pattern unlike the other species present at the site. It persists throughout the year and makes its maximum growth in late October and November. It spreads vegetatively by means of short stolons, thus a constant supply of nutrients and moisture is available to young growth. It is taller than most other plants on the site during the spring period and exerts influence through shading. As growth slows down during the summer, erect young stems and their leaves become prostrate smothering out young plants of annuals and soft grasses. The result of this is to reduce the space available for seed germination and the growth of young seedlings. However, where Ranunculus sardous is present as a dense growth of vegetative stolons Holcus lanatus does not smother growth. It has been observed by the author that after the collapse of Holcus stems and leaves, Ranunculus grows up through the litter layer produced. Ovington (1950) investigated the invasion of abandoned pastures by Holcus mollis L. in Scotland. He found that Holcus mollis was able to grow effectively under large amounts of vegetation refuse, unlike the other major grass present (Deschampsia flexuosa L.).

It is concluded that Holcus lanatus, with its growth habit similar to H. mollis, would have a similar smothering effect. This effect, together with the general growth in height and breadth of other plants on the Hillcrest site, is sufficient to account for the effects observed over the 7 year period of succession.

Changes in the Fauna

The soil beneath an old grass sward, except in the immediate vicinity of the surface, constitutes a very stable environment which is not subject to large or sudden alterations in conditions. The changes exhibited by the fauna are therefore more likely to be responses to the cumulative influence of small variations in a number of factors than to the overriding effect of large changes in a single factor. Nevertheless, the complexity of the soil as an environment makes it virtually impossible in field studies to take into consideration all the variables which might conceivably influence the nature, size or distribution of the microarthropod fauna. Further progress in the unravelling of these relationships is unlikely to be made until the behaviour of individual species in relation to single environmental factors has been more fully determined under controlled conditions in the laboratory.

In August 1966 at Hillcrest, under short pasture conditions, burrowers constituted 36% of the total population, litter-dwellers (Acarina and Collembola) 13%, Mollusca 5%, surface-dwellers 5%, scarabid larvae 2%, stratiomyid larvae 17%, and all other groups totalled 23%.

In August 1968, the pasture composition had changed in height and litter depth, while coarse grasses had increased their extent of cover. The percentage figures for this period were : burrowers 44%, litter-dwellers 15%, Mollusca 1%, surface-dwellers 4%, scarabid larvae 5%, stratiomyid larvae 26%, and other groups 5%.

The summer of 1968-69 exhibited moderate drought conditions and the numbers of fauna in several groups received a set-back, which is reflected by the percentages of those groups near to the soil/vegetation interface. Thus, in 1970, burrowers constituted 29% of the population (down 15% from 1968), litter-dwellers 11% (down 2%), Mollusca 1% (down 2%), surface-dwellers showed no change at 4%, scarabid larvae 2% (down 3%), but stratiomyid larvae increased to 29% (up 3%), while other groups increased to 24% (up 19%). Mr. C. Wilcocks, Ruakura A.R.C., (personal communication, 1972) recorded this change in stratiomyid population, as did W. Kain, Ruakura A.R.C.,(personal communication, 1972) in scarabids.

The last survey in the series (February 1972) showed that some groups had recovered to their pre-drought population levels. For example, litter-dwellers reached 11%, Mollusca 2% and surface-dwellers 3%, and other groups 18%. The low figures for burrowers (4%) are accounted for if the time of year is considered. In February, most annelids, particularly Lumbricus rubellus, have withdrawn to depths greater than the depth to which the samples were taken. No scarabid larvae were obtained in the February samples, although larvae were present in samples from the area adjacent to the Hillcrest site. The greatly increased numbers of stratiomyid larvae (62%) are part of a general increase experienced by other areas (Wilcocks - personal communication, 1972).

The statements made so far would indicate that no great changes occurred at Hillcrest in the composition of the fauna over a 7 year period. Changes have occurred in floral composition, however, and the effects upon the fauna of increased cover can best be illustrated thus :

FAUNAL COMPOSITION, HILLCREST AND NEWSTEAD, FEBRUARY, 1970

(Figures given are to the nearest percent)

	Hillcrest	Newstead
Burrowers	27	30
Litter-dwellers	12	4
Mollusca	5	0
Surface-dwellers	10	3
Scarabid larvae	6	16
Stratiomyid larvae	34	38
Others	6	9

It would seem that those groups at Newstead most affected by the lack of vegetation and litter cover are those living close to the surface, i.e., litter-dwellers, surface-dwellers and Mollusca. All three groups show a marked drop in numbers when compared with the Hillcrest site. Burrowers show little comparative difference in population and neither do stratiomyid larvae. Scarabid larvae are greater in population percentage at Newstead than Hillcrest. Both

Fenemore (1966) and Miller (1921) mention that preference for oviposition in adult scarabids in short pasture. The variation in numbers could perhaps be explained in the two sites if vegetation length is considered.

SUMMARY

Long-term change in the biota at Hillcrest is apparent only in the flora. From a short grass pasture of stable composition, rapid progression occurred to a few dominant forms of plants. The author suggests that the succession in the flora is due to the domination of low-growing, less vigorous plants by tall shade-producing plants which smother young growth. The basic composition of the fauna remains unchanged after a 7 year period. Short-term effects may occur with unfavourable low moisture conditions at the surface, particularly upon surface-dwellers, but to some extent the effects of desiccation are ameliorated by the maintenance of a strong covering of vegetation and its associated litter layer.

TABLE 10

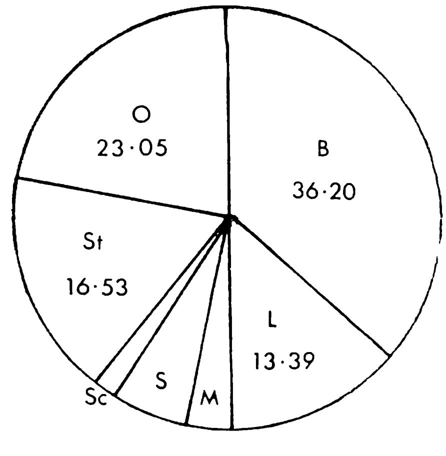
CHANGE OF FAUNAL COMPOSITION - HILLCREST - 1966-1972. Figure given is percentage of total fauna for sampling time.

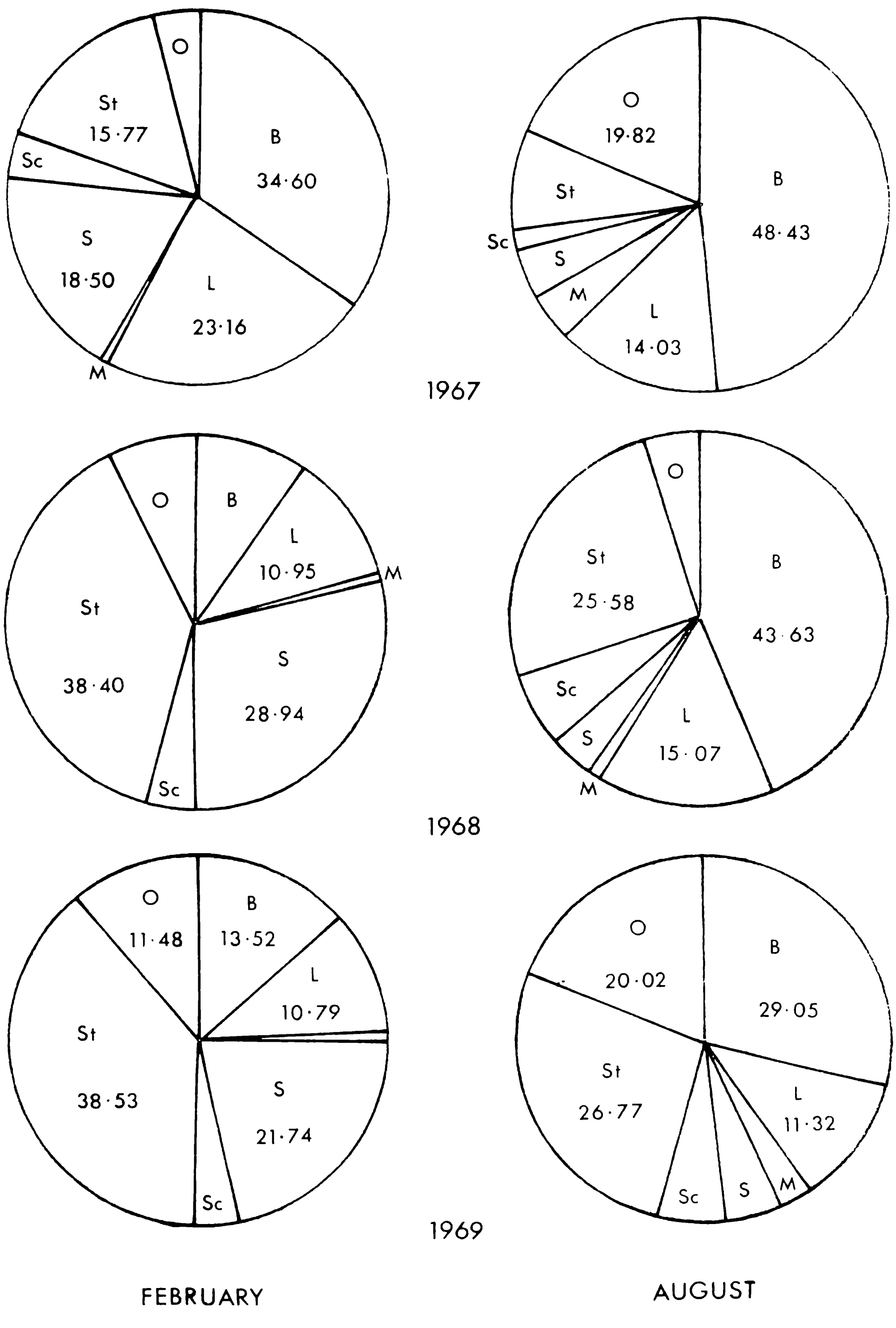
	1966	1967		1968		1969		1970		1971		1972
	A	F	A	F	A	F	A	F	A	F	A	F
Lumbricidae	33.06	31.10	44.60	7.79	36.36	11.47	23.83	24.90	23.01	11.18	20.76	1.58
Enchytraeids	3.14	3.50	3.83	1.86	7.27	2.05	5.22	2.02	5.84	2.12	4.52	2.52
Mollusca	3.26	0.23	3.82	0.19	0.53	0.68	2.83	5.54	2.13	1.35	4.27	2.21
Acarina	12.46	18.65	13.68	9.65	11.82	8.22	9.14	9.34	8.75	4.82	6.35	9.46
Araneida	1.28	3.73	0.93	9.65	0.78	10.27	1.09	2.02	1.01	10.98	1.47	0.63
Collembola	0.93	4.51	0.35	1.30	3.25	2.57	2.18	3.11	2.02	3.66	3.30	1.89
Staphylinidae	2.56	7.54	2.20	5.19	1.95	4.28	1.41	2.02	1.23	3.28	1.10	0.63
Carabidae adult	0.82	2.49	0.46	2.97	0.65	2.40	0.76	3.73	1.35	3.66	1.71	0.32
Scarabidae larvae	1.75	3.73	1.27	4.08	6.23	3.26	5.66	6.54	1.91	1.54	0.48	0.00
Stratiomyidae larvae	16.53	15.77	8.46	38.40	25.58	38.53	26.77	33.61	29.40	34.88	33.94	61.83
Formicidae	1.16	4.74	0.58	11.13	0.39	4.79	1.09	1.56	0.79	6.55	0.61	0.63
Others	23.05	4.01	19.82	7.79	5.19	11.48	20.02	5.70	22.56	15.98	21.49	18.30
Total numbers in 25 samples	859	578	863	539	770	584	919	627	891	519	819	634

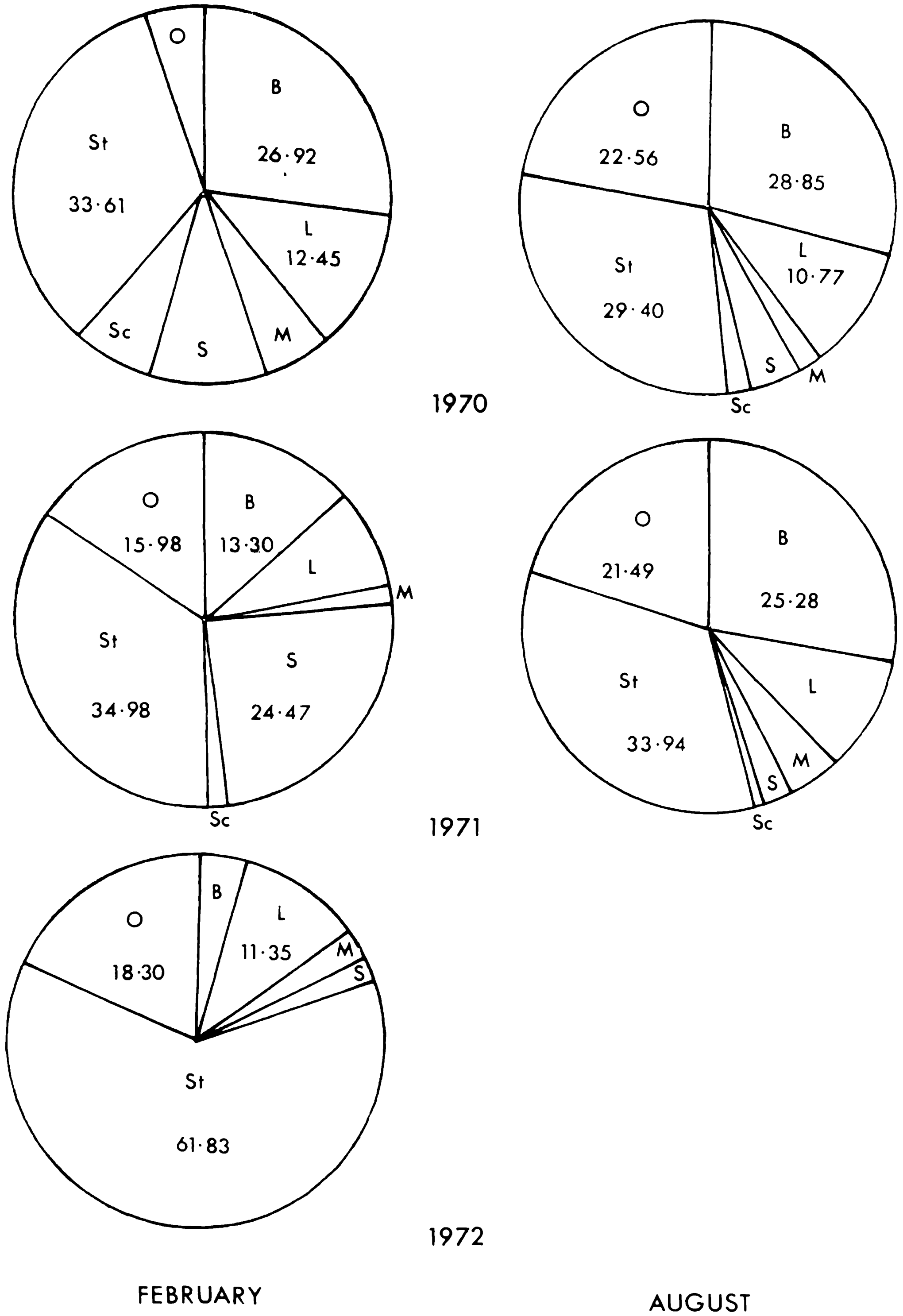
CHANGE OF FAUNAL COMPOSITION - HILLCREST

B	Burrowers
L	Litter dwellers
M	Mollusca
S	Surface dwellers
Sc	Scarabid larvae
St	Stratiomyid larvae
O	Other groups

Sectors show percent of total fauna for each sampling time.







Surface dwellers	:	Staphylinidae, Carabidae, Formicidae Araneida.
Litter dwellers	:	Acarina, Collembola.
Burrowers	:	Lumbricidae, Enchytraeidae.

SECTION 9 : LONG-TERM EFFECTS OF VEGETATION REMOVAL

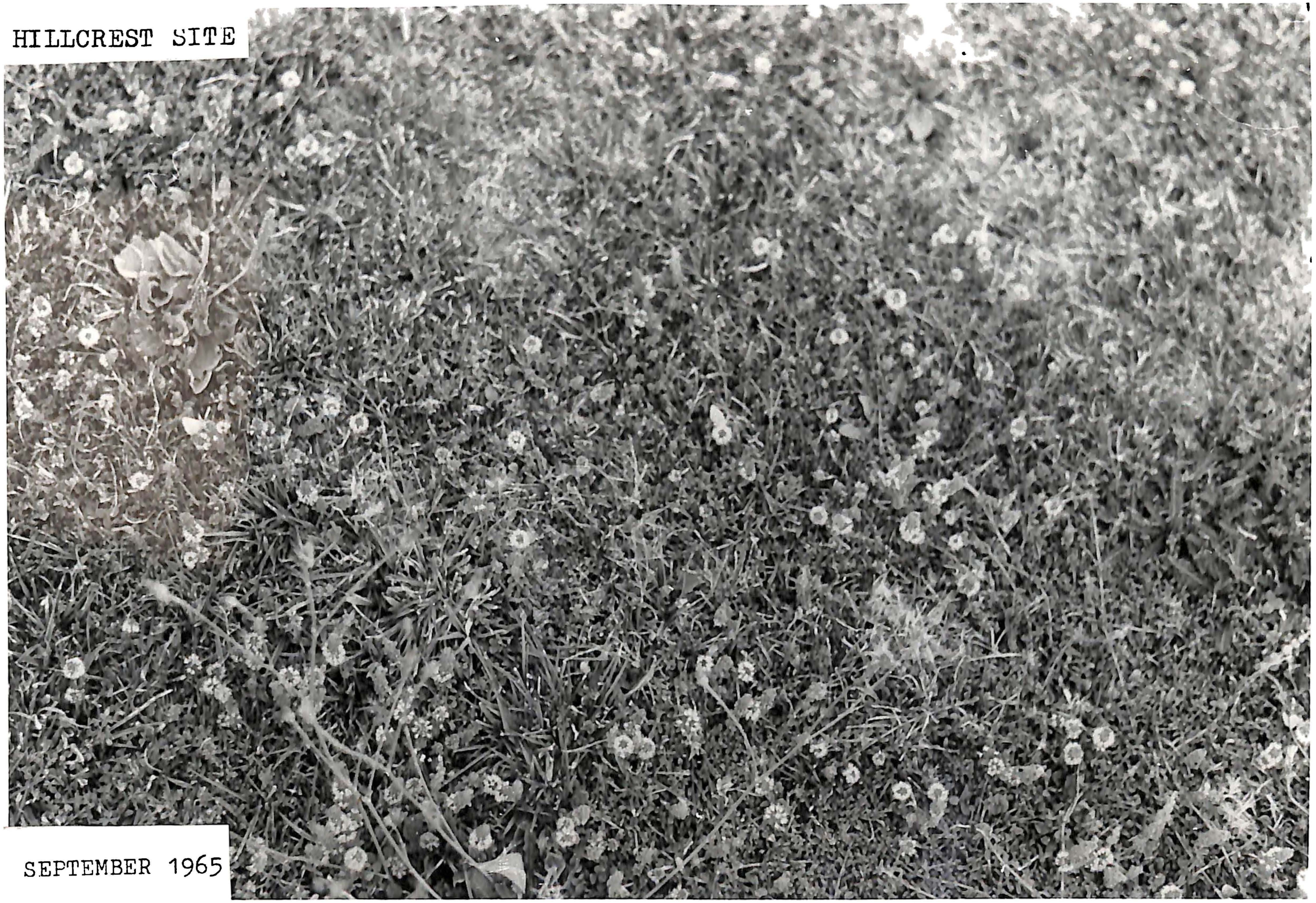
From an examination of the three photographs which follow, it can be seen that where vegetation is not systematically removed from an area, tall growing plants of a few species dominate and suppress rosette forms, annuals and soft grasses.

The pasture on the Hillcrest site (September 1965) before enclosure, when mowing was maintained, consists of Achillea millefolium, Cerastium glomeratum, Lolium perenne, Mentha pulegium, Plantago lanceolata, Plantago major, Poa annua and Trifolium repens. Litter is absent and the height of vegetation does not exceed 4 cm.

By September 1968, after enclosure and the cessation of vegetation removal, fewer species occur at the site - the majority being tall growing species. Achillea millefolium produces a tall growth form. Dactylis glomerata forms dense clumps, while Lolium perenne and Agrostis tenuis, although growing strongly, have a firm undergrowth of Ranunculus sardous. Rumex obtusifolium forms clumps. The mean height of vegetation is 45 cm, although clumps may grow to 70 cm. The mean litter depth is 4 cm.

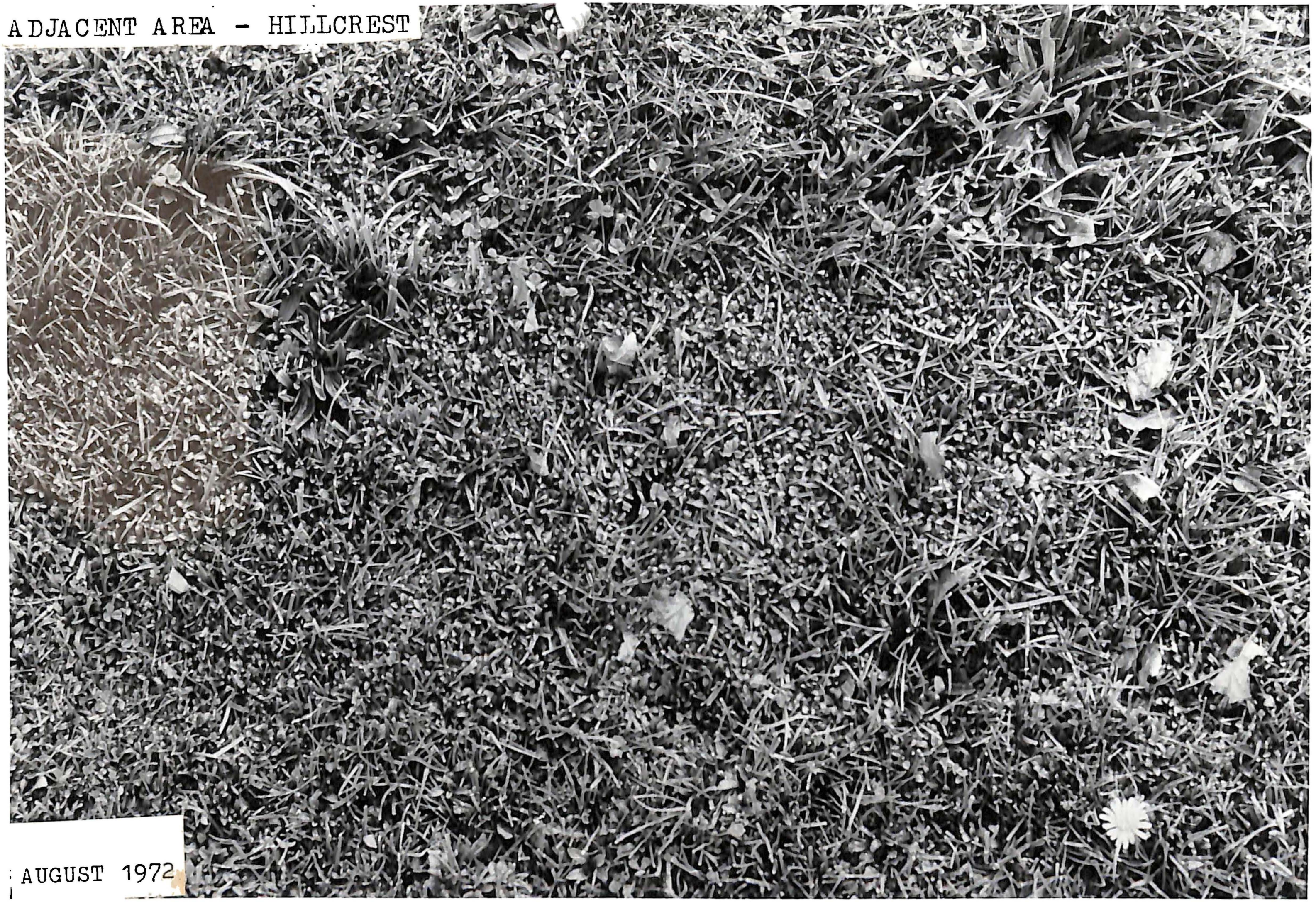
By contrast, an area immediately adjacent to the Hillcrest site retains in August 1972 essentially the same structure and composition as did the Hillcrest site in September 1965. Vegetation removal by systematic mowing has suppressed tall growing plants. Litter is absent and the height of vegetation does not exceed 4 cm. Those species present are Achillea millefolium, Cerastium glomeratum, Hypochaeris radicata, Lolium perenne, Mentha pulegium, Plantago lanceolata, Poa annua and Trifolium repens.

HILLCREST SITE



SEPTEMBER 1965


HILLCREST SITE
SEPTEMBER 1968



ADJACENT AREA - HILLCREST

AUGUST 1972

TABLE 11

KEY:
- A annuals
- C coarse grasses
- CL clover
- P perennials
- R rosettes
- S soft grasses
- T trace

PLANTS - PERCENTAGE COVER

SPECIES MAXIMUM FOR EACH YEAR

(Grouped as per Allan, H. 1940)

		1966	1967	1968	1969	1970	1971	1972
Achillea millefolium L.	P	7.80	6.84	12.18	10.29	15.12	16.24	15.52
Agrostis gigantea Roth	S	0.10	0.14	0.05	0.01	T	Nil	Nil
Agrostis tenuis Sibth.	S	37.60	50.04	45.88	41.71	35.55	27.72	10.94
Anagallis arvensis L.	A	T	0.09	0.01	T	T	T	T
Anthoxanthum odoratum L.	S	0.05	T	T	Nil	Nil	Nil	Nil
Bellis perennis L.	P	0.05	0.01	T	T	T	T	T
Bromus unioloides (Willd.) Beauv.	C	Nil	0.09	0.14	0.85	1.24	13.15	15.20
Cerastium glomeratum Thuill.	A	0.40	0.05	0.03	0.03	0.01	T	0.05
Cirsium vulgare (Savi) Ten.	R	T	T	0.01	0.02	0.05	0.05	0.05
Crepis capillaris (L.) Wallr.	R	T	1.42	1.04	0.05	0.52	T	T
Dactylis glomerata L.	C	0.14	1.33	0.24	0.18	1.09	4.29	0.47
Holcus Lanatus L.	C	0.72	0.95	1.16	2.00	2.38	7.19	58.10
Hypochaeris radicata L.	R	0.09	0.09	0.14	0.09	0.07	0.04	T
Lolium perenne L.	S	1.75	2.08	2.00	5.04	1.49	4.95	4.37

Lotus uliginosus Schkuhr	CL	0.40	0.09	0.92	0.71	2.81	3.05	2.39
Mentha pulegium L.	P	12.20	9.45	1.46	0.33	0.19	0.41	0.08
Modiola caroliniana (L.) Don.	A	0.05	0.05	0.09	T	T	T	T
Paspalum dilatatum Poir.	C	0.10	0.10	0.05	0.05	0.09	0.33	0.24
Paspalum paspaloides Scribn.	C	0.36	0.36	0.48	0.33	2.33	0.48	0.43
Plantago lanceolata L.	R	0.30	3.00	2.42	0.24	1.00	0.48	0.38
Plantago major L.	R	0.70	1.33	3.23	0.29	0.09	0.05	T
Poa annua L.	S	0.24	0.38	0.05	T	T	Nil	Nil
Prunella vulgaris L.	P	0.30	1.47	0.09	0.01	T	T	T
Ranunculus sardous Crantz	P	0.80	0.43	0.24	4.73	6.17	13.84	18.82
Rumex obtusifolius L.	P	2.48	4.67	2.76	5.61	3.14	1.33	2.71
Solanum nigrum L.	A	0.28	0.20	0.16	0.13	0.10	0.12	0.14
Soliva sessilis R. & P.	A	0.10	0.05	T	T	Nil	Nil	Nil
Stellaria media (L.) Vill.	A	T	T	T	T	T	T	T
Taraxacum officinale Weber	R	0.20	0.62	1.24	0.81	0.96	0.09	0.09
Trifolium repens L.	CL	40.00	27.80	27.40	25.83	27.42	6.19	1.43
Veronica sepyllifolia L.	P	T	0.04	T	T	T	T	Nil

TABLE 12

FLORA - PERCENTAGE COVER - Maximum for January/June Key: . absent from samples; T trace only; + increase; - decrease; o no change		Hillcrest 1967	Hillcrest 1972	Newstead 1972	Tamahere 1972	Hillcrest adjacent area 1972
yarrow Achillea millefolium L.	+	7.80	15.12	.	.	7.50
redtop Agrostis gigantea Roth	-	0.10	Nil	.	.	0.05
browntop Agrostis tenuis Sibth	-	37.60	10.94	27.00	20.00	35.00
scarlet pimpernel Anagallis arvensis L.	o	T	T	.	.	T
sweeet vernal Anthoxanthum adoratum L.	-	0.05	Nil	.	.	0.01
daisy Bellis perennis L.	-	0.05	T	2.00	1.00	0.09
prairie grass Bromus unioloides Beauv.	+	Nil	15.20	.	.	0.01
annual mouse-eared chickweed Cerastium glomeratum Thuill	-	0.10	0.05	3.00	.	0.09
Scotch thistle Cirsium vulgare Ten.	+	T	0.05	T	T	T

hawksbeard Crepis capillaris L.	o	T	T	T	0.05	T
cocksfoot Dactylis glomerata L.	+	0.14	0.47	.	.	0.15
Yorkshire fog Holcus lanatus L.	+	0.72	58.10	.	.	1.00
cat's ear Hypochaeris radicata L.	-	0.09	T	0.05	0.01	1.00
perennial ryegrass Lolium perenne L.	+	1.75	4.37	30.00	30.00	1.80
lotus major Lotus uliginosa Schkuhr	+	0.40	2.39	.	.	0.38
pennyroyal Mentha pulegium L.	-	12.20	0.08	.	.	11.57
creeping mallow Modiola caroliniana L.	-	0.05	T	.	.	0.08
paspalum Paspalum dilatatum Poir	+	0.10	0.24	10.00	5.00	0.20
Mercer grass Paspalum paspaloides Scribn.	o	0.36	0.43	40.00	.	0.40
narrow-leaved plantain Plantago lanceolata L.	o	0.30	0.38	20.00	16.50	0.32

broad-leaved plantain Plantago major L.	-	0.70	T	0.10	0.18	0.68
annual Poa Poa annua L.	-	0.24	Nil	0.08	0.10	0.20
selfheal Prunella vulgaris L.	-	0.30	T	.	0.02	0.28
hairy buttercup Ranunculus sardous Crantz	+	0.80	18.82	.	.	1.00
broad-leaved dock Rumex obtusifolius L.	o	2.48	2.71	.	.	2.50
black nightshade Solanum nigrum L.	-	0.28	0.14	.	.	0.30
Onehunga weed Soliva sessilis R. and P.	-	0.10	Nil	2.00	4.00	0.10
chickweed Stellaria media L.	o	T	T	.	.	T
dandelion Taraxacum officinale Weber	-	0.20	0.09	7.00	5.20	0.22
white clover Trifolium repens L.	-	40.00	1.43	30.00	40.00	41.00
turf speedwell Veronica serpyllifolia L.	-	T	Nil	.	.	T

CHANGE OF VEGETATION COMPOSITION - HILLCREST

TABLE 13

Figures indicate the percentage cover for each group

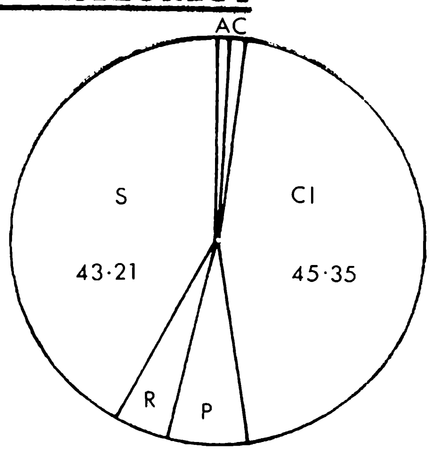
	Annuals		Coarse Grasses		Clovers		Perennials		Rosettes		Soft Grasses	
	Feb.	Aug.	Feb.	Aug.	Feb.	Aug.	Feb.	Aug.	Feb.	Aug.	Feb.	Aug.
1966	.	0.46	.	0.53	.	45.35	.	6.30	.	4.15	.	43.21
1967	0.40	0.33	0.00	2.15	40.48	27.80	21.10	13.29	0.42	3.31	37.60	53.12
1968	0.09	0.15	3.25	3.90	22.17	30.25	25.23	8.62	10.10	1.14	38.61	55.94
1969	0.05	0.05	4.32	11.89	23.47	29.70	20.81	15.37	2.00	1.91	49.30	41.13
1970	0.05	0.29	6.17	26.73	25.20	7.41	29.13	18.36	5.50	1.62	33.95	45.59
1971	0.00	0.00	25.11	51.88	9.24	5.20	31.41	12.19	1.57	0.54	32.67	30.19
1972	0.00	.	52.45	.	1.12	.	31.08	.	0.15	.	15.20	.

TABLE 13a

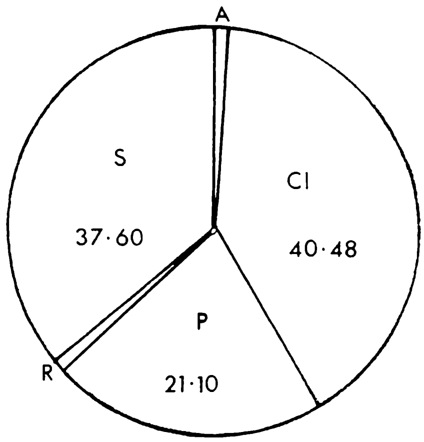
CHANGE IN VEGETATION COMPOSITION - HILLCREST

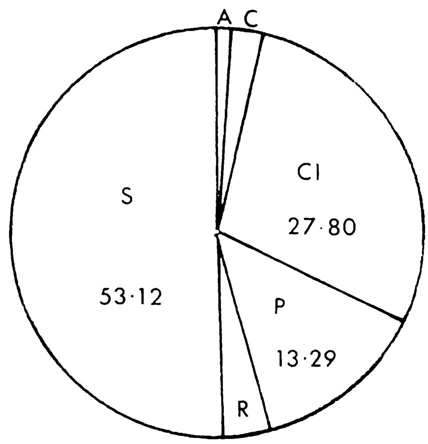
A	Annuals
C	Coarse grasses
CL	Clovers
P	Perennials
R	Rosettes
S	Soft grasses

Sectors show percent cover.

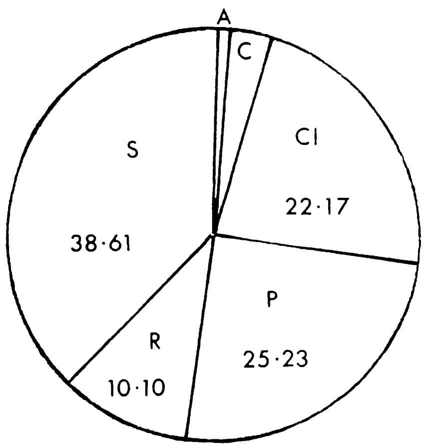


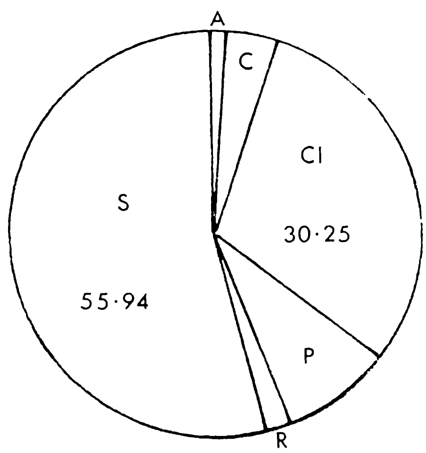
1966



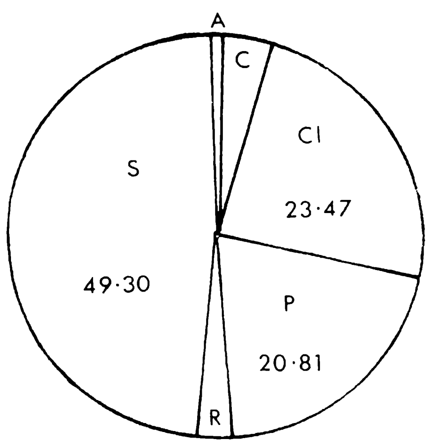


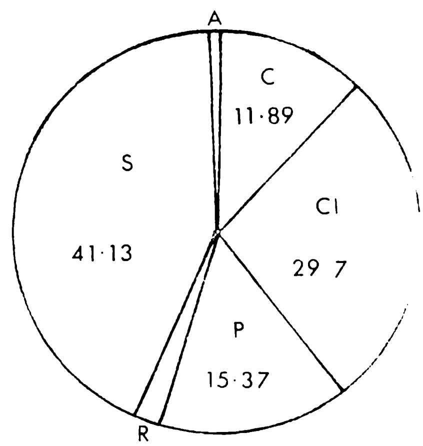
1967





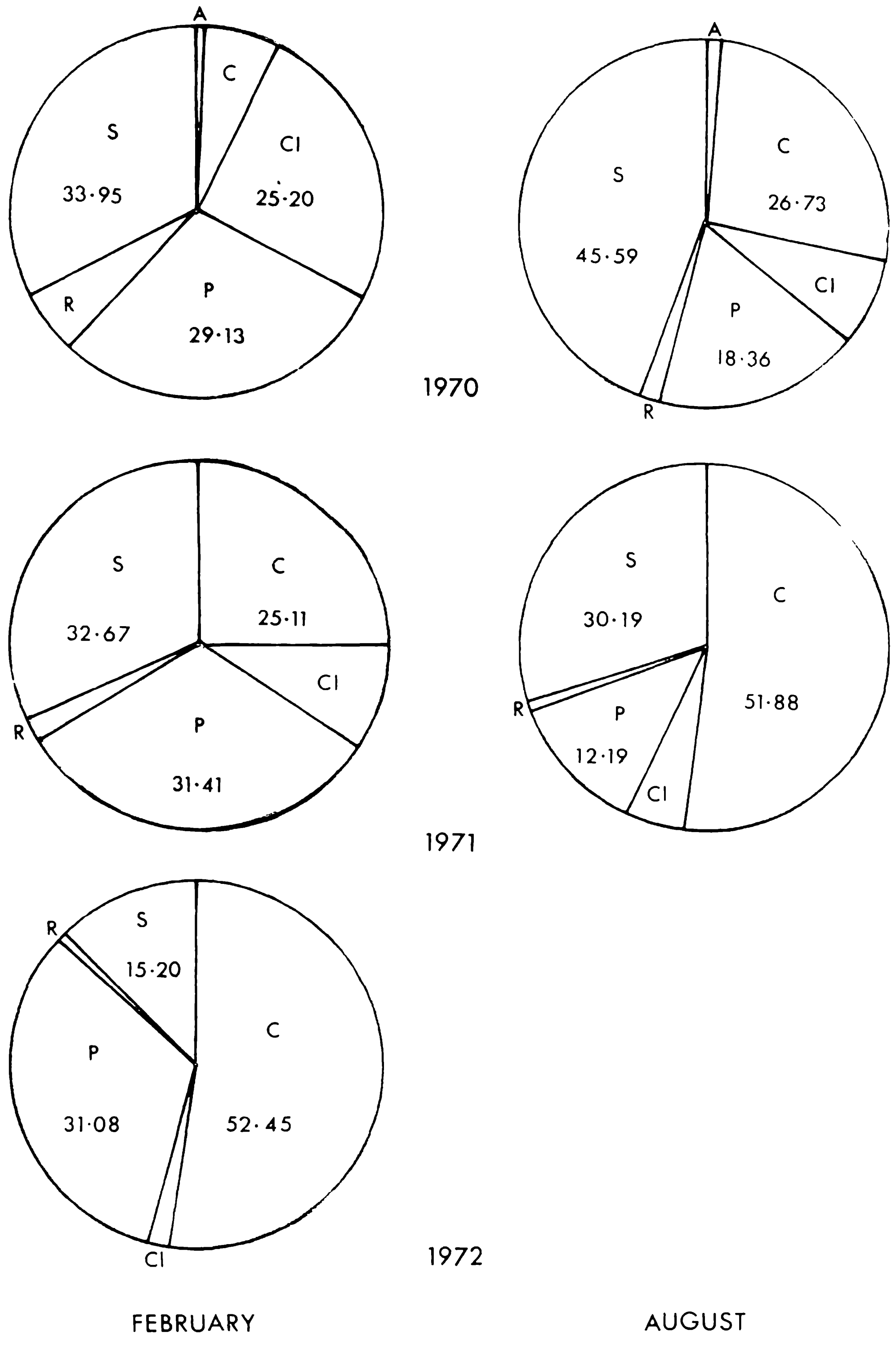
1968





1969

FEBRUARY AUGUST



A
C
S
Cl
33·95
25·20
R
P
29·13
1970
A
C
S
26·73
45·59
Cl
P
18·36
R
S
C
32·67
25·11
Cl
R
P
31·41
1971
S
C
30·19
R
P
51·88
12·19
Cl
R
S
15·20
C
P
31·08
52·45
Cl
1972
FEBRUARY
AUGUST

SECTION 10 : THE SEQUENCE OF THE FLORAL SUCCESSION AT HILLCREST

Upon the floral distribution diagrams (1966-1972) a grid overlay was plotted using 5 quadrats (2 m x 2 m) at right angles to the advancing front.

The south-west corner (quadrat A) in 1966 was dominated by white clover (Trifolium repens). Quadrat C was on the front and Quadrat E was dominated by browntop (Agrostis tenuis).

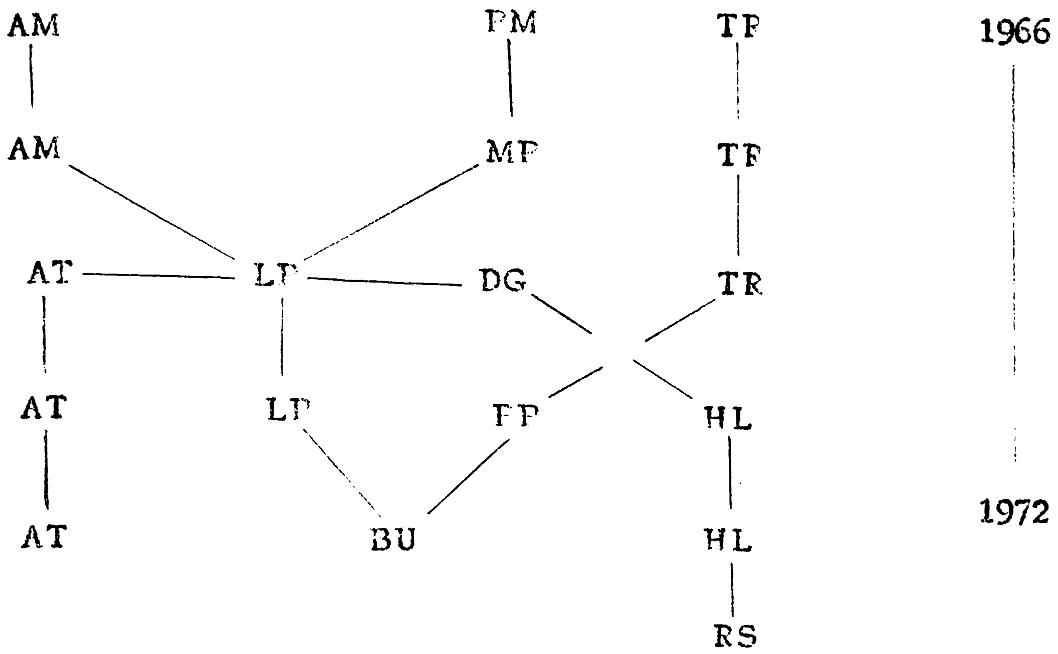
By plotting the species change for February of each year (1966-1972), the sequence was shown for each quadrat. The succession was shown to be as follows :

1. Yarrow (Achillea millefolium), broad-leaved plantain (Plantago major) and white clover (Trifolium repens) are the dominant species when the pasture is short.
2. Pennyroyal (Mentha pulegium) replaces broad-leaved plantain.
3. Browntop (Agrostis tenuis), perennial ryegrass (Lolium perenne) and cocksfoot (Dactylis glomerata) replace yarrow and pennyroyal.
4. Yorkshire fog (Holcus lanatus) and Paspalum paspaloides replace white clover and cocksfoot.
5. Prairie grass (Bromus unioloides) replaces Paspalum paspaloides and perennial ryegrass, culminating in a pasture dominated by browntop, prairie grass and Yorkshire fog.

It should be noted that where creeping buttercup (Ranunculus sardous) has established as a dominant, replacement does not seem to occur, but some over-growth of Yorkshire fog does occur to produce co-dominance.

The mean rate of advance of the vegetation fron was 0.99 m/year.

THE FLORAL SEQUENCE



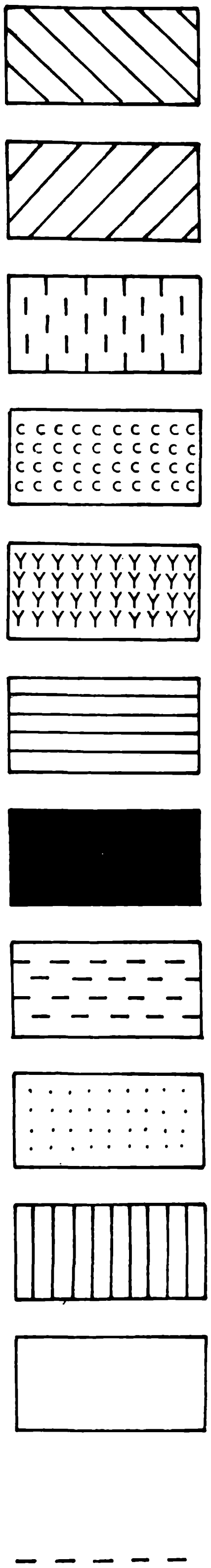
KEY

AM	Achillea millefolium	yarrow
AT	Agrostis tenuis	brown top
BU	Bromus unioloides	prairie grass
DG	Dactylis glomerata	cocksfoot
HL	Holcus lanatus	Yorkshire fog
LP	Lolium perenne	perennial ryegrass
MP	Mentha pulegium	pennyroyal
PM	Plantago major	broad-leaved plantain
PP	Paspalum paspaloides	Mercer grass
RS	Ranunculus sardous	creeping buttercup
TR	Trifolium repens	white clover

VEGETATION SUCCESSION - HILLCREST

1966 - 1972

KEY TO MAJOR GROUPS



Achillea millefolium

Agrostis tenuis

Bromus unioloides

Dactylis glomerata

Holcus lanatus

Lolium perenne

Mentha pulegium

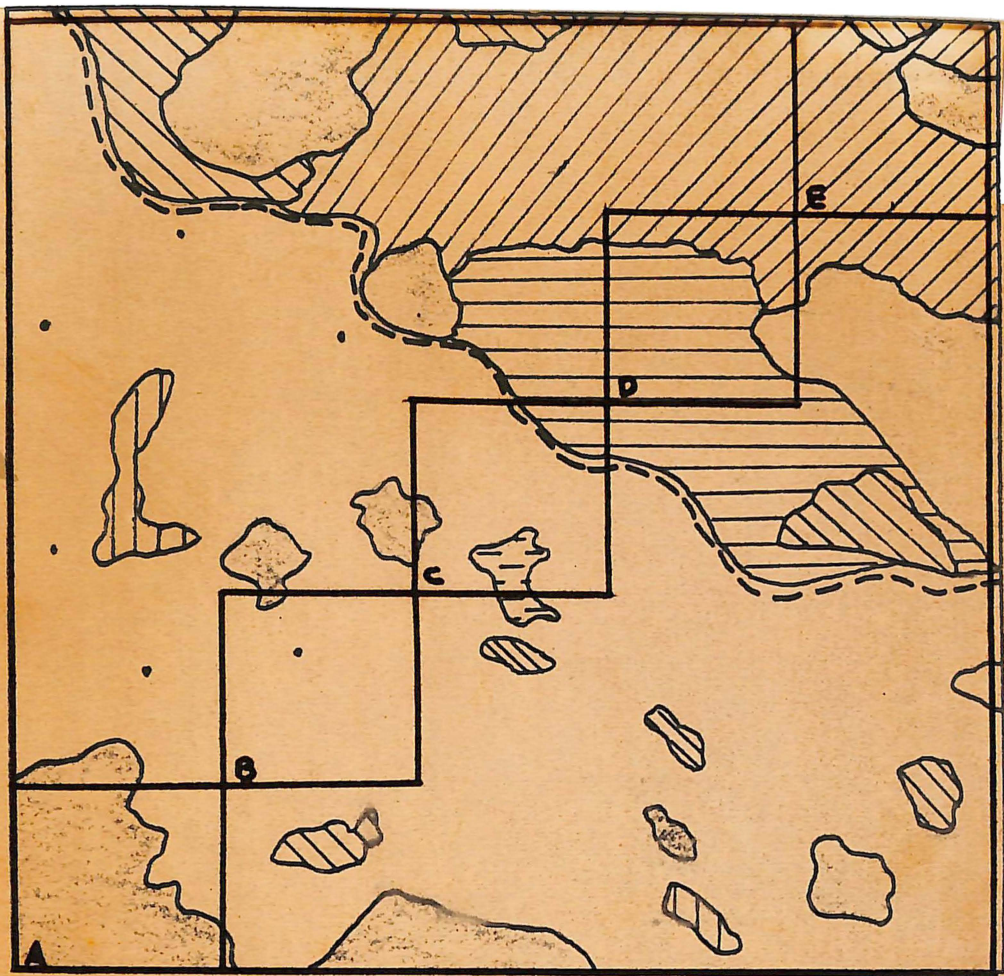
Paspalum paspaloides

Plantago major

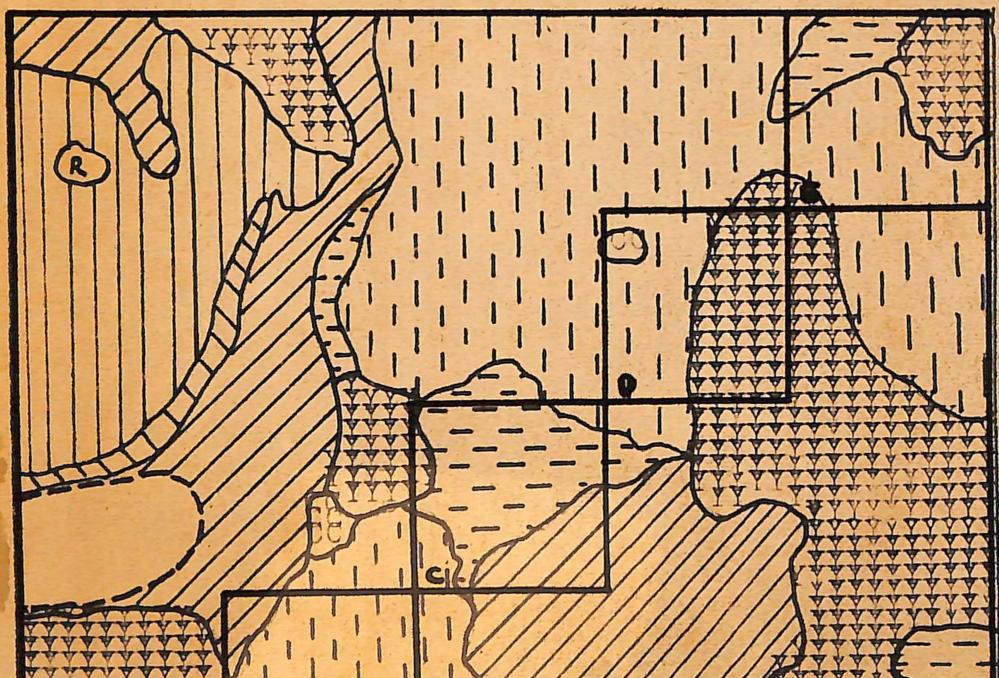
Ranunculus sardous

Trifolium repens

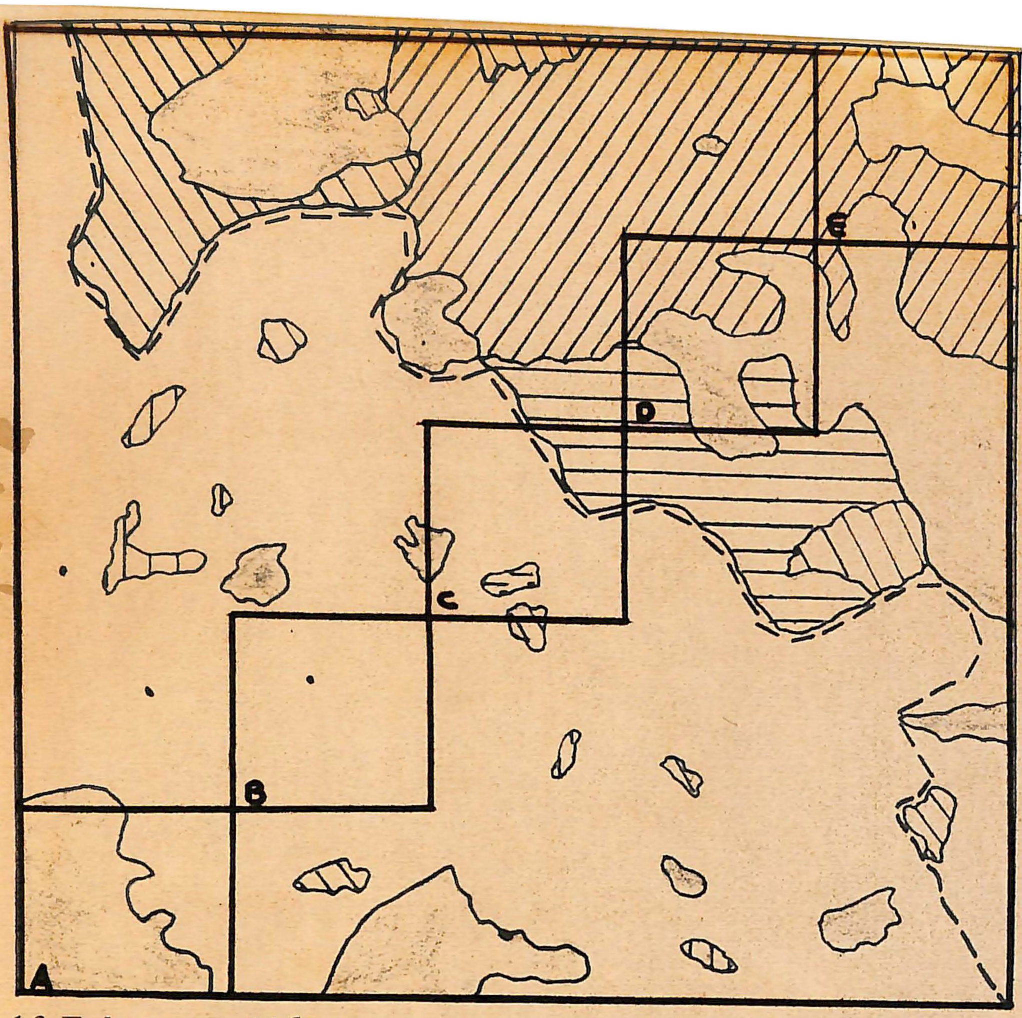
Vegetation front



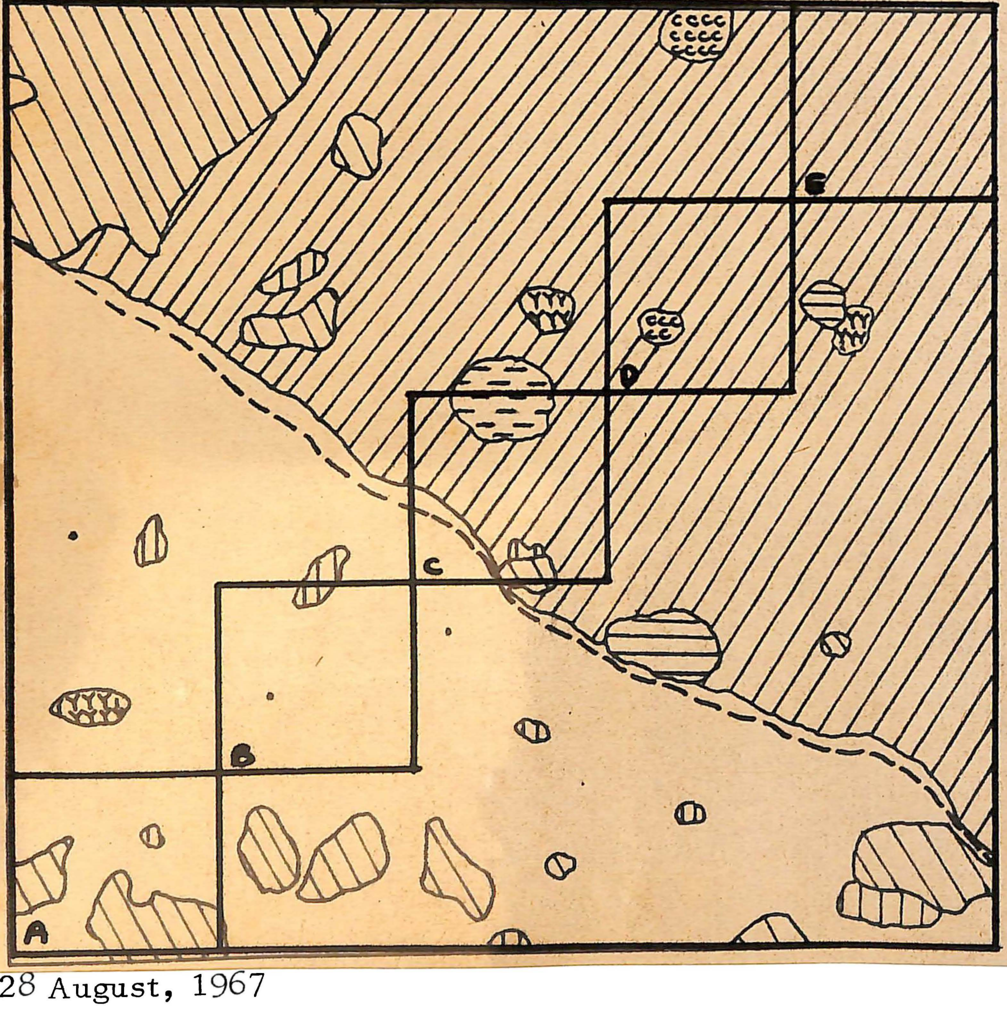
29 August, 1966



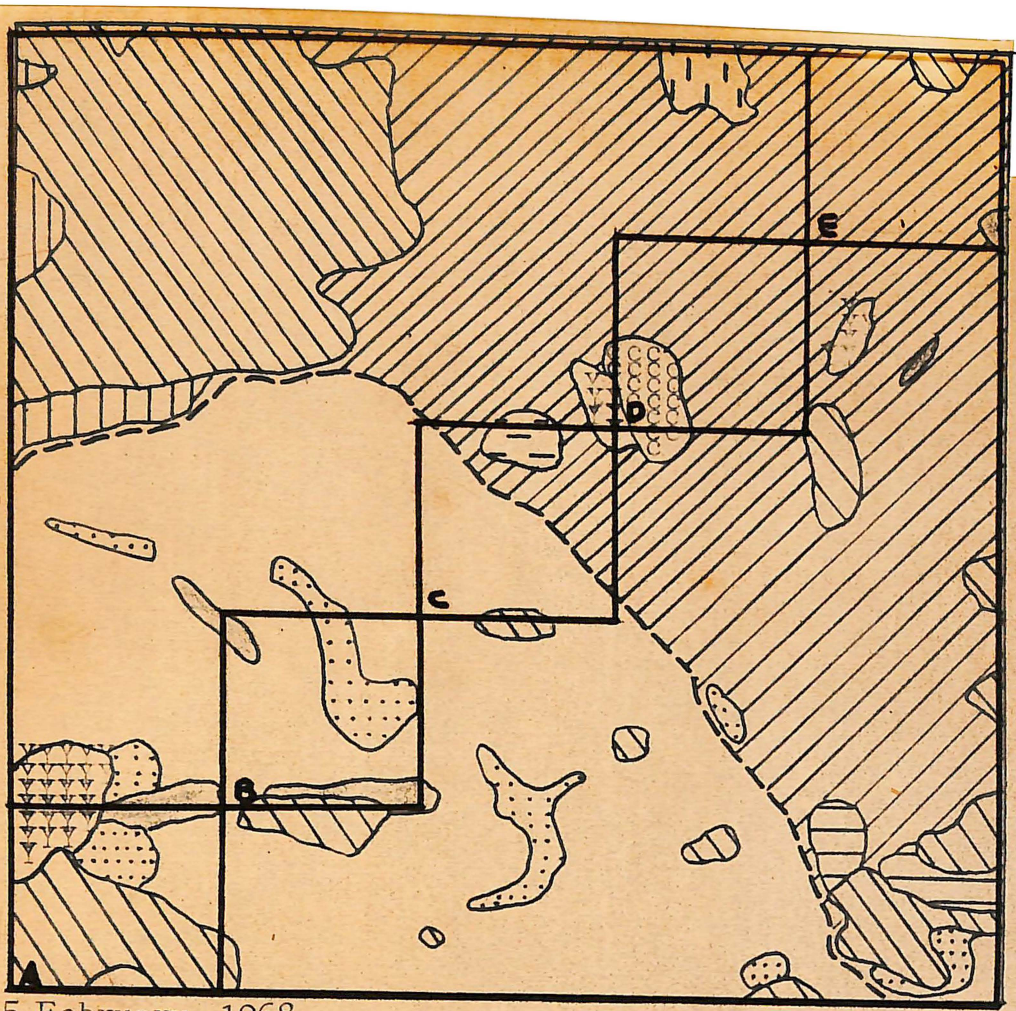
10 February, 1972



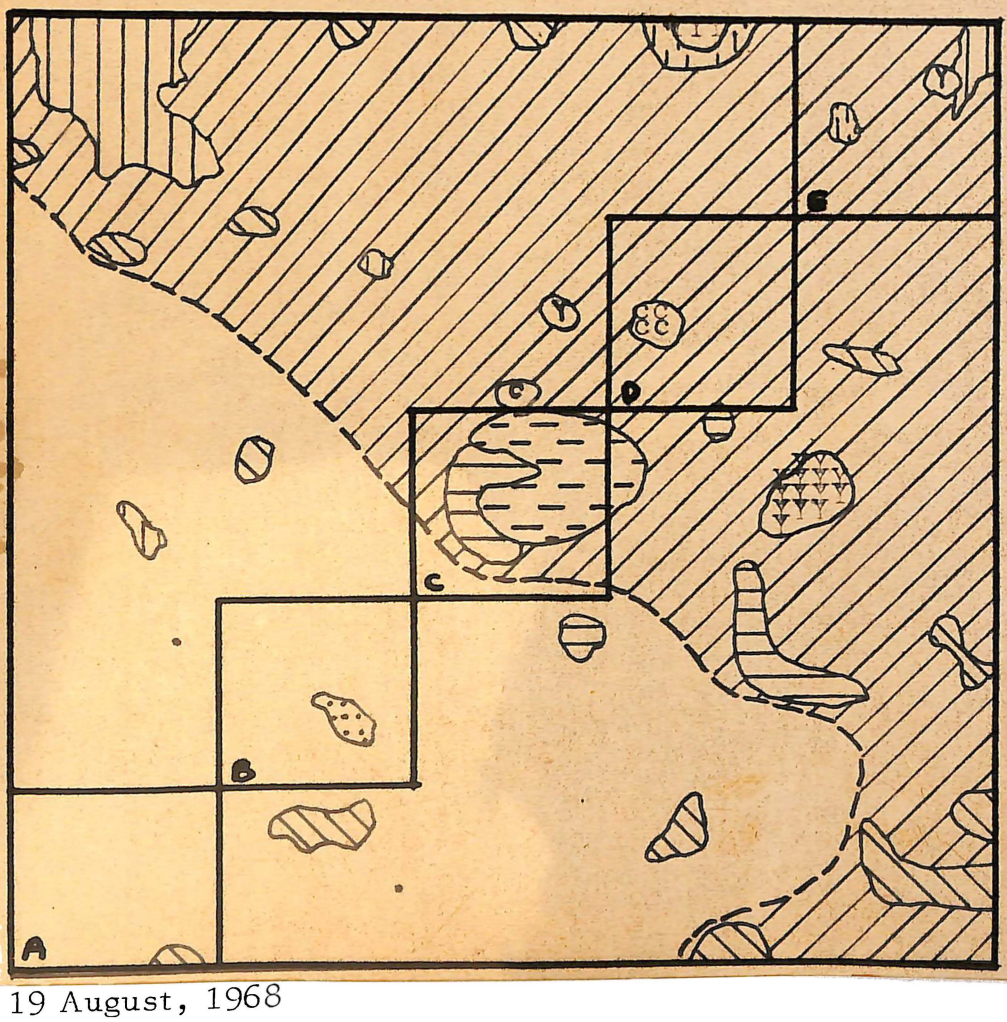
13 February, 1967



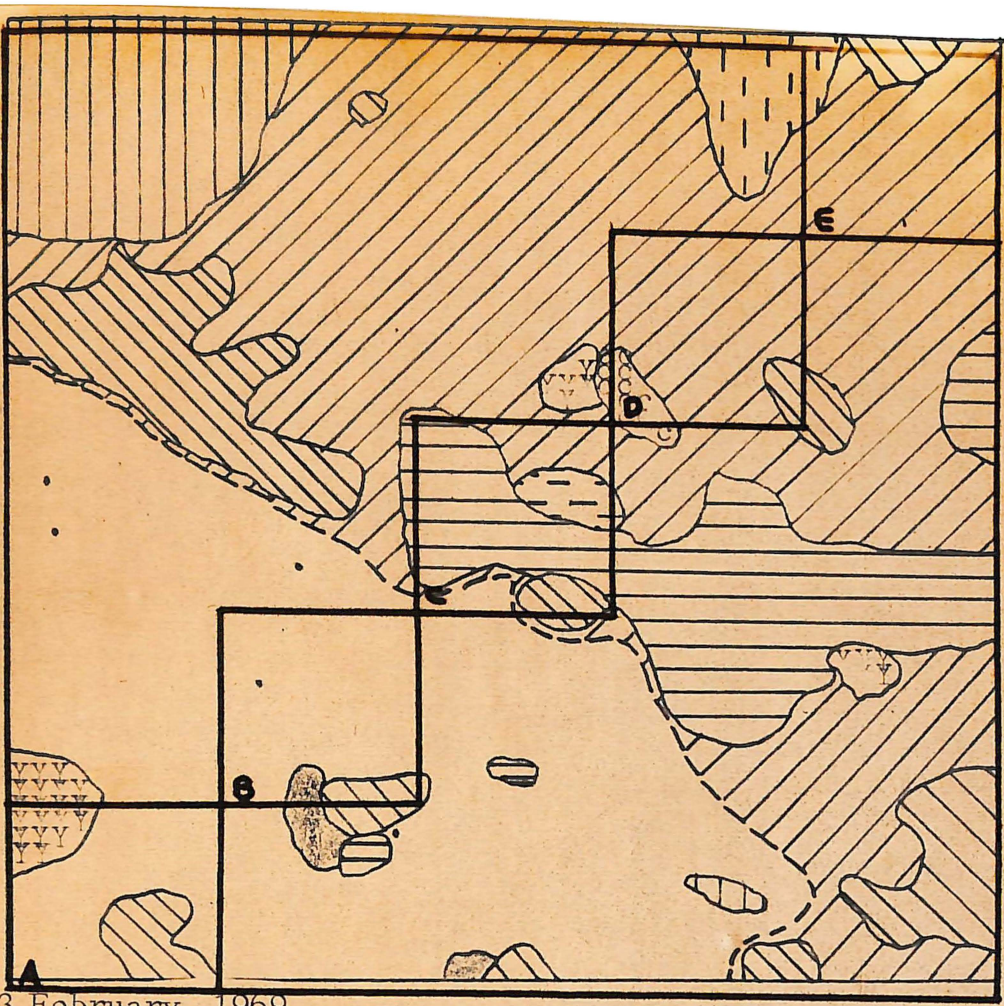
28 August, 1967



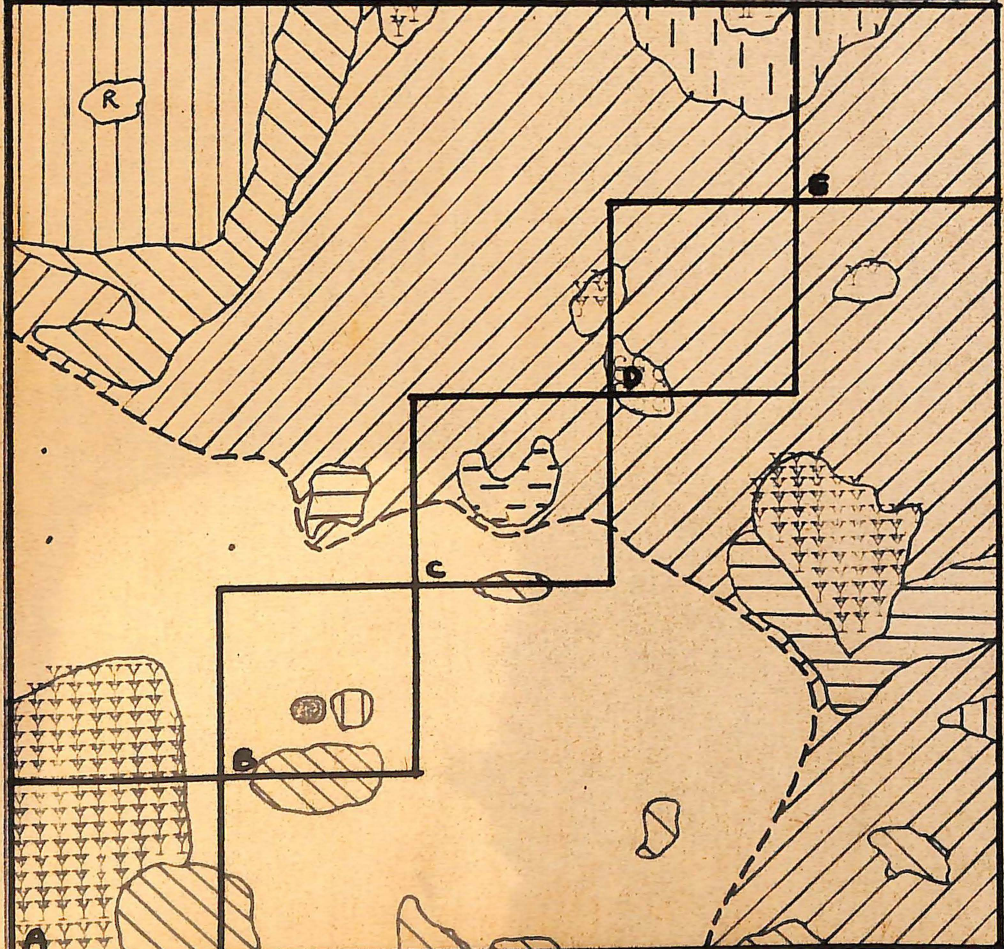
5 February, 1968



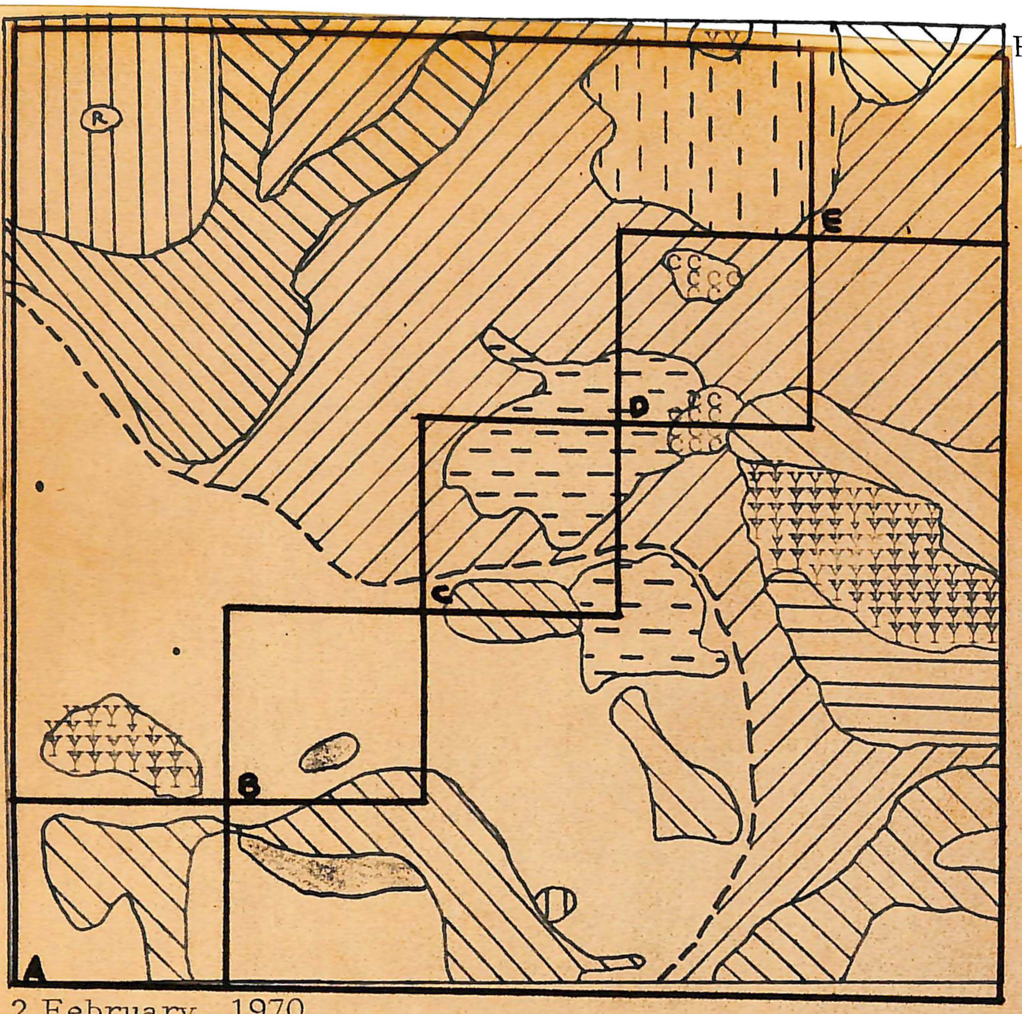
19 August, 1968



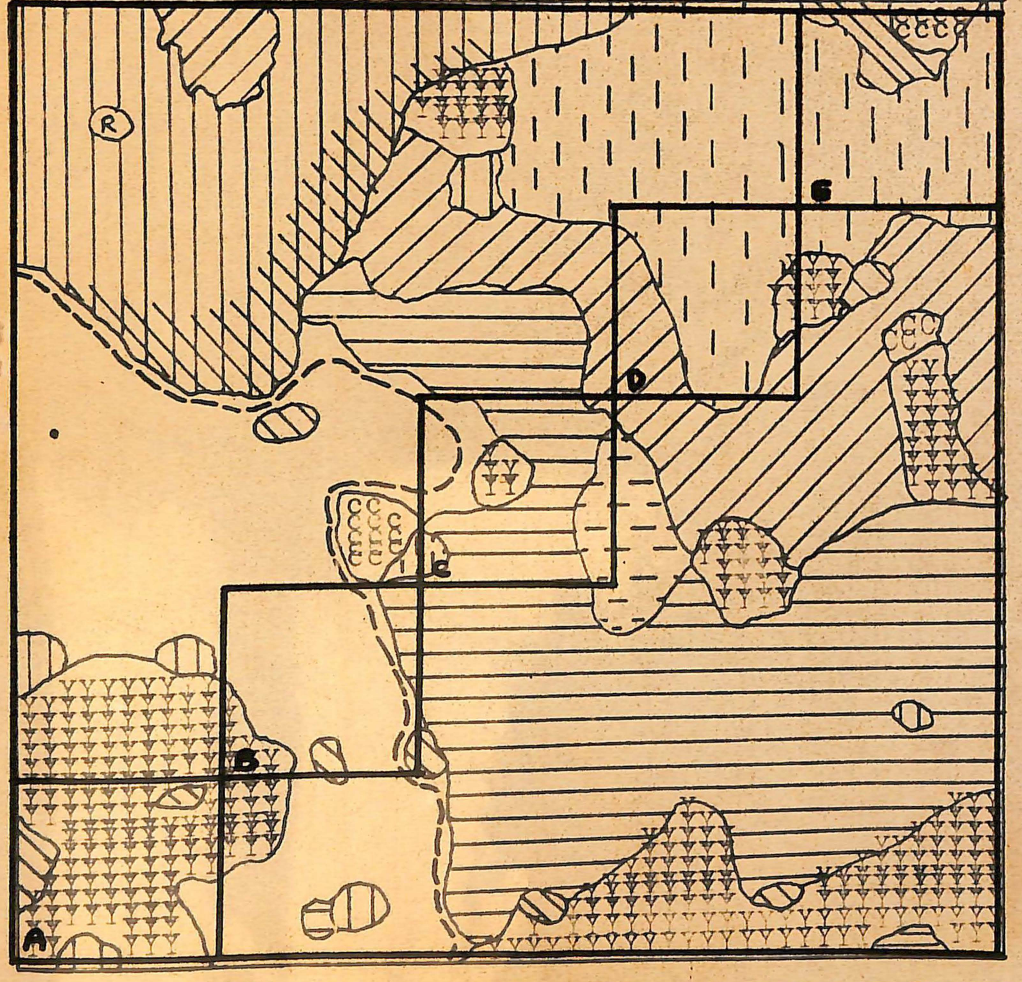
3 February, 1969



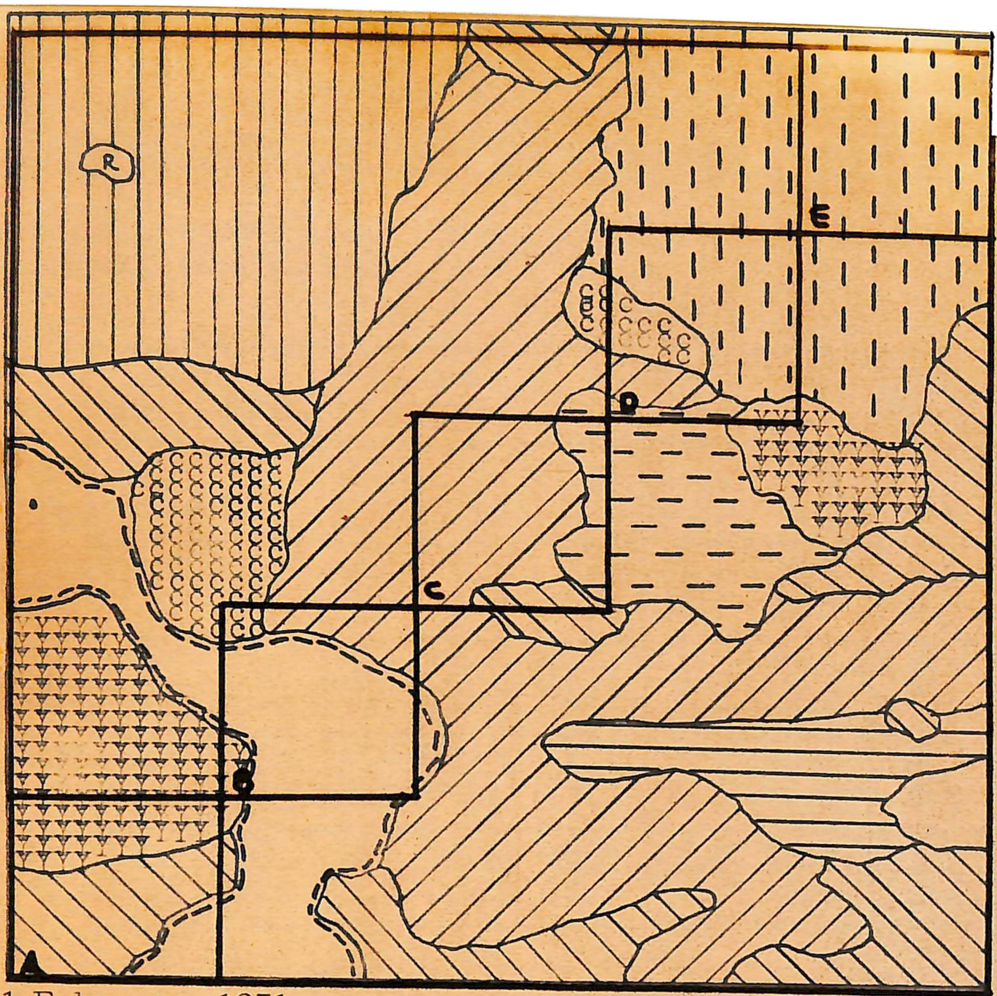
18 August, 1969



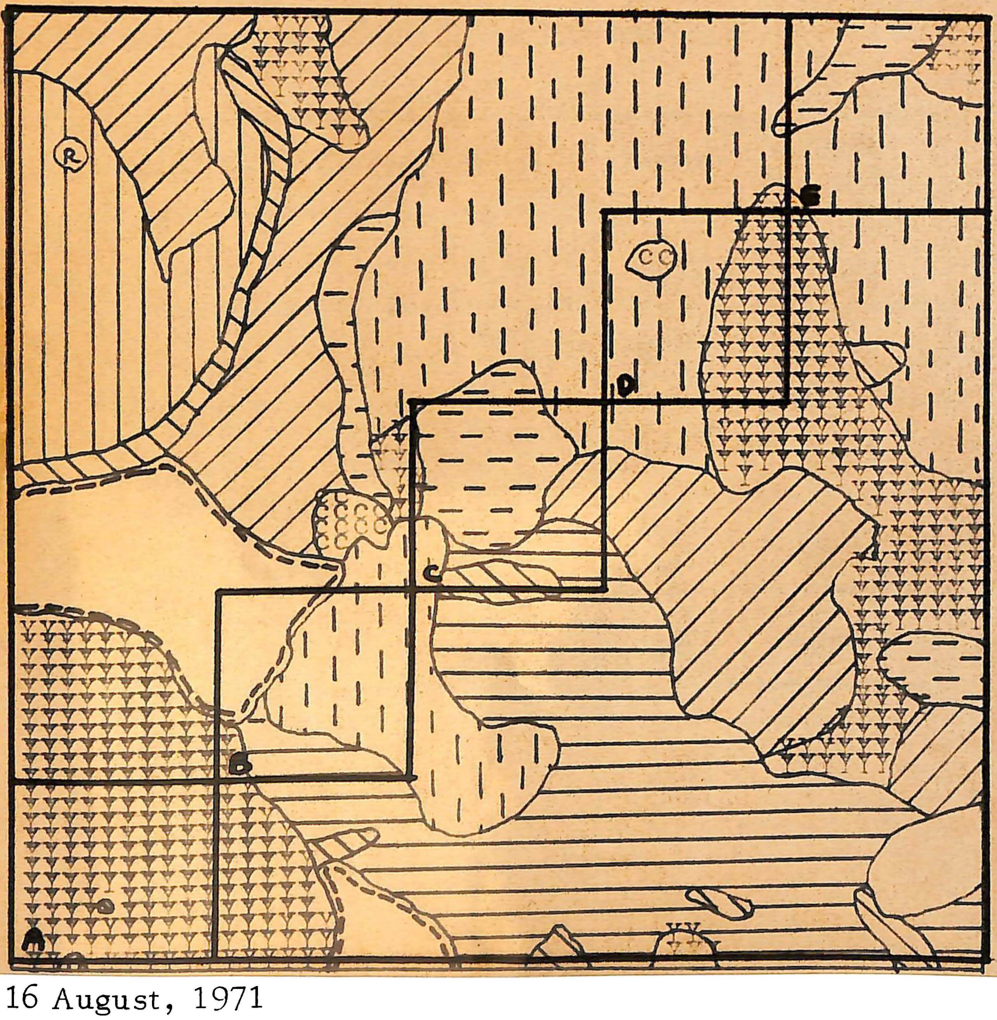
2 February, 1970



17 August, 1970



1 February, 1971



16 August, 1971

HILLCREST PLOT - MOVEMENT OF VEGETATION FRONT

A. Distance (metres) from North-East Marker and Percentage Increase of Distance:

		West		Centre		East		Dis.	% Inc.
		Dis.	% Inc.	Dis.	% Inc.	Dis.	% Inc.	Mean	Mean
1967	F	6.5	•	6.5	•	6.5	•	6.5	•
	A	9.0	38.0	7.5	15.5	8.0	11.0	8.2	21.5
1968	F	11.0	18.0	7.5	0.0	8.5	6.2	9.0	8.1
	A	11.0	5.5	8.0	6.7	11.5	35.3	10.2	15.8
1969	F	11.0	0.0	8.0	0.0	11.5	0.0	10.2	0.0
	A	11.0	0.0	8.0	0.0	11.5	0.0	10.2	0.0
1970	F	11.0	0.0	9.0	12.5	11.5	0.0	10.5	4.2
	A	11.0	0.0	9.0	0.0	11.5	0.0	10.5	0.0
1971	F	11.0	0.0	9.5	5.5	12.0	4.4	10.8	3.3
	A	11.5	5.5	10.0	5.3	12.0	0.0	11.2	3.6

F = February
A = August

B. Distance (metres) which Front has Advanced:

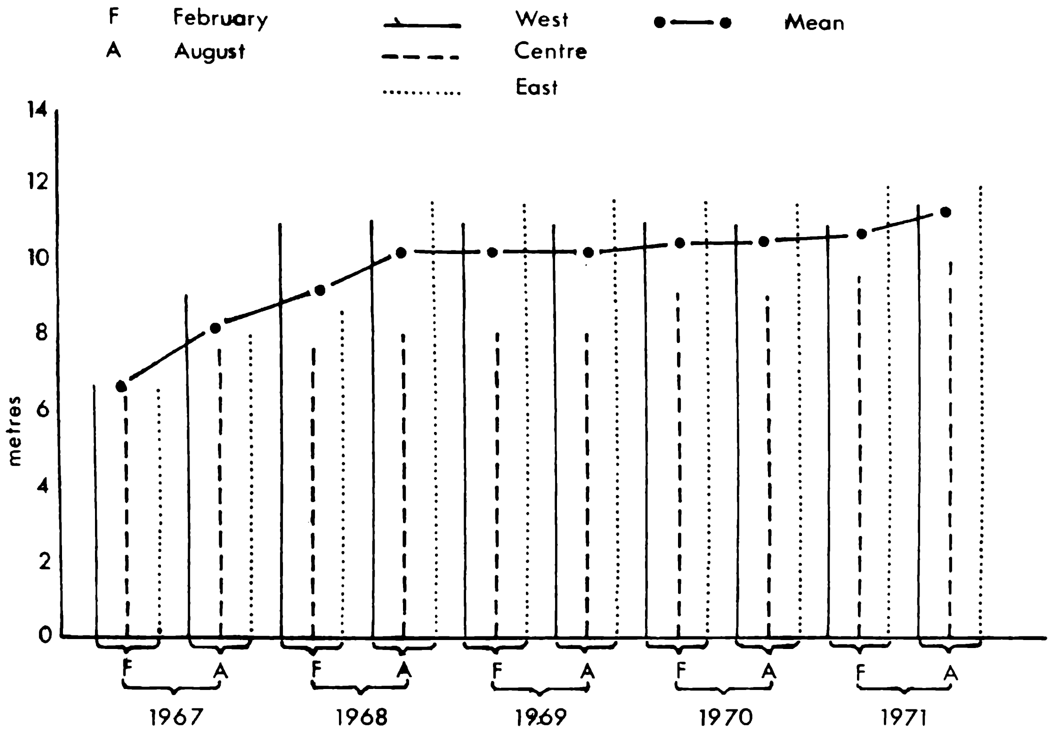
		West	Centre	East	Mean	Distance per year
1967	F	•	•	•	•	•
	A	2.5	1.0	1.5	2.10	2.10
1968	F	2.0	0.0	0.5	0.83	1.99
	A	0.0	0.5	3.0	1.16	
1969	F	0.0	0.0	0.0	0.00	0.00
	A	0.0	0.0	0.0	0.00	
1970	F	0.0	1.0	0.0	0.30	0.30
	A	0.0	0.0	0.0	0.00	
1971	F	0.0	0.5	0.5	0.30	0.60
	A	0.5	0.5	0.0	0.30	

F = February
A = August

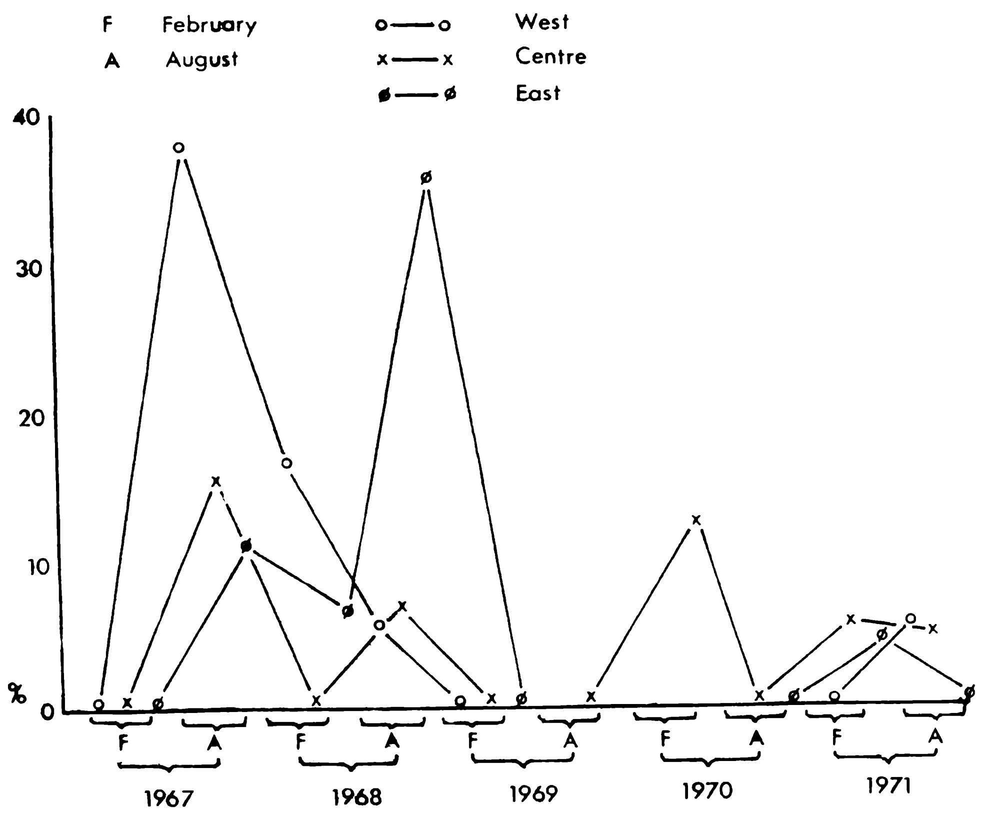
Total Advance : 4.99 m
Mean Rate : 0.99 m/year

SUPPRESSION OF TRIFOLIUM REPENS BY OTHER SPECIES - HILLCREST (1967-1971)

DISTANCE OF FRONT FROM NORTH-EAST MARKER



PERCENTAGE INCREASE OF ADVANCE OF FRONT



SECTION 11 : SOME COMMON FAUNA

Elateridae (p.166)

Adults occur during November/January at the 3 sites, but never in great numbers. The maximum number recorded was in January (15,000 per ha). The mean length for 54 specimens is 12.3 mm, with a range of 11.1-13.2 mm. Eggs occur in the top 1 mm of soil during November/January, but not in great numbers. At Hillcrest, larvae have a mean monthly population of 77,000 per ha, with a January maximum of 178,000, and a late November minimum of 14,000 per ha. They are uniformly distributed through the top 5 cm of soil. The mean length for 75 larvae is 21.1 mm with a size range of 17.0-23.2 mm. No apparent damage to pasture could be observed, but damage to agricultural root crops is reported in Britain (Kühnelt, 1963) where it is regarded as an important pest. Feeding trials with larvae and adults by the author using pasture plants from Hillcrest were unsuccessful.

Carabidae (p.166)

The adult carabids collected during the period of survey lived on the soil surface amongst the accumulated leaf litter, while larvae occurred in the 0-1 cm level of the soil, retreating to 1-2 cm in June. Eggs are found in clumps of 10-15 just below the soil surface during November/January, with the greatest numbers of clumps in December. Larvae have a mean monthly population of 67,000 per ha, with the maximum (99,000) in March, and the minimum (27,000) in July. Adults have a mean monthly population of 54,000, a December maximum of 96,000 per ha and a July minimum of 25,000. Feeding experiments in the laboratory by the author show that both the larvae and adults fed readily on whole small larvae of Costelytra zealandica and triturated Lumbricus rubellus.

Costelytra zealandica (p.167)

This endemic scarabid feeds in the soil during the larval stage on the roots of most pasture plants (Miller, 1921). The author has found that larvae are not associated with dense clumps of Mentha pulegium at any of the 3 sites. By August, most larvae have entered the final instar, and pupate 12 cm below the soil surface to emerge as adults in October. The main emergence occurs in October and November, but pupae have been found at Newstead in early March. Small larvae occur deepest in the soil (down to 15 cm), but the larger the larvae are the closer they come to the surface. At Hillcrest, larval numbers show a mean monthly figure of 510,000 per ha, with a maximum of 716,000 per ha in April, and a minimum of 25,000 per ha in October. Numbers of 1.3 millions per ha have been recorded at Hillcrest. Population figures are similar at Tamahere, but at Newstead populations are usually 10% lower than the other 2 sites during summer. Fenemore (1966) considers that where heavy infestations of larvae occur, shallow rooted grasses are eliminated and weeds rapidly become established in pastures.

Creophilus oculatus (p.167)

This is the largest of several species of staphylinids recovered on the sites. It is readily recognised by its black colour, short elytra, orange spots posterior to each eye, and the pungent odour when disturbed. The mean length of 28 specimens recovered was 12.8 mm. It occurs in surface litter and down to 4 cm depth. It is not found on the surface at Newstead and Tamahere during January, February and

March. The author has observed Creophilus feeding on dead Limax maximus and Lumbricus rubellus. A mean monthly population at Hillcrest is 301,000 per ha, with a maximum in March of 568,000, and a minimum in October of 114,000 per ha.

Thallasohelix zelandiae (p. 156)

This small endemic snail is found occasionally during autumn, winter and spring at Hillcrest, Newstead and Tamahere. The pale yellow-brown helicoid shell has a mean diameter of 3.2 mm and a mean height of 1.1 mm (62 specimens). The body is medium grey with white specks dorsally, while the underside of the "foot" is cream. Little is known of the ecology of Thallasohelix but Powell (1957, p.189) suggests that it feeds on finely comminuted leaf fragments and soil algae. Egg clumps were observed once only, in June. Live individuals are found under leaf litter on the surface of the soil, but bleached shells are recovered during the summer from the top 2 cm of soil. Numbers (estimate only) may be about 1,200 per ha at Hillcrest.

Agriolimax reticularis (p.155)

This is the common grey field slug, introduced from Europe. The extended length is 3-4 cm. The mean length of 67 slugs collected was 3.6 cm. Colour is variable from blue-black to white, but usually is grey-brown to brownish-yellow. The monthly mean at Hillcrest is 100,000 per ha, but the maximum (November) may be 1.3 millions per ha. Egg-laying at the base of vegetation clumps occurs at Hillcrest throughout the year except for January, February and March, and reaches a maximum in late November. 97% are found in the top 8 cm of soil except in January to March when population numbers are reduced. Runham and Hunter (1970) state that Agriolimax can offset high depletion rates due to drought and frost by their high rate of reproduction. During summer, there is a tendency for aggregation under the densest layers of litter at Hillcrest, where moisture content is highest. Pallant (1969) reports that in British woodland, food consists of 53.4% Ranunculus repens, 23.9% Urtica dioica, 12.3% "grass", 21.2% arthropods (aphids, small diptera) and the remainder other vegetation. This author has observed Agriolimax actively feeding on leaves of Ranunculus sardous just after light rain in April.

Helix aspersa (p.155)

The common garden snail, introduced from Europe, is more numerous at Newstead and Tamahere (12,000 per ha) in November than at Hillcrest. Here it is sporadic in occurrence but does not attain more than 2,000 per ha at any time. It is a surface-dweller entirely, and has been observed by the author to feed on young leaves of Trifolium repens, flower-heads and green capsules of Ranunculus sardous, although occasionally young flower stems of Plantago lanceolata are removed at ground level. Major egg-laying occurs in November, but there may in some "early spring" years be a minor surge of laying in late August.

Allolobophora caliginosa (probably form trapezoides) (p.154)

The extended length of mature worms is 4-10 cm. The mean length of 200 specimens collected at Hillcrest was 8.9 cm. The anterior end is pinkish and the posterior end is grey without the sheen on the dermal surface observed in Lumbricus rubellus. It occurs to some depth in the soil, but is found typically down to 30 cm. The majority are found in the 12-29 cm level. Cocoons are pale yellow darkening to green at each end. The surface of the cocoon is smooth without fibres. 120 cocoons were measured giving a mean length of 3.5 mm, mean width of 2.7 mm, and a length/width ratio of 1.3 mm. Evans and Guild (1947) have obtained similar figures for samples collected in the United Kingdom where Allolobophora is endemic. The maximum number of cocoons occurs in October and the minimum in February. Waters (1955) records populations of 7 million per ha under New Zealand perennial ryegrass and white clover pasture. The numbers at Hillcrest show a monthly mean of 3.17 millions per ha, and a maximum of 5.6 millions per ha in November. Similar numbers occur at Newstead although January to March figures are less than at Hillcrest. Food consists of dead roots and herbage.

Limax maximus (p.154)

This large tiger slug was sporadic in occurrence at Hillcrest. The extended length of 54 slugs was 10-21 cm, with a mean length of 16 cm. It was reported by Runham and Hunter (1970) that it feeds on other slugs, but will eat other food including fungi and decaying matter. It has been observed at Hillcrest that recently dead Limax are fed upon by the staphylinid Creophilus oculatus. There is some indication from Runham and Hunter that British staphylinids are predators on slugs. Although Limax is found sporadically at Hillcrest, in November it has been recorded at 5,000 per ha. They are fewer at Newstead and absent from Tamahere. Egg-laying occurs in November under vegetation and in small depressions in the ground, particularly at night after rain.

Enchytraeidae (p.153)

Little appears to be known about the New Zealand species and identification is difficult. They occur regularly at all 3 sites, and at

Hillcrest have a mean monthly population of 425,000 per ha. A peak in numbers occurs in May (1,200,000 per ha) and another smaller peak in October (800,000 per ha). During January, February and March the population falls to 200,000 per ha, and also in September (100,000 per ha). The mean length of 428 mature speciments collected in June was 23.3 mm. The size range was 15.1-48.3 mm. When soil conditions are moist, they are uniformly distributed down to 15 cm below the soil surface, but during dry conditions the majority are found in the 3-4 cm layer. Wallwork (1970) records population peaks in April and October, with lowest numbers in June, although he states that the size of enchytraeid populations in British pastures is subject to sudden and violent fluctuation. The cause is unknown. Food materials consist basically of plant fragments and fungi, although inorganic matter may account for 20% of gut contents.

Lumbricus rubellus (p.153)

This introduced European earthworm is the dominant lumbricid at all 3 sites, occurring down to 30 cm, but the majority are in the top 15 cm of soil. The colour is red-brown with a marked dorsal sheen, while the ventral side is cream. The size range of 385 specimens collected at Hillcrest was 25-150 mm with a mean extended length of 74 mm. Aestivation during mid-summer is particularly evident at Newstead and Tamahere and occurs 10 cm below the soil surface. The maximum number of cocoons is produced in October and the minimum in February. They are medium brown with a greenish tinge. The surface appears fibrous yet is smooth textured. Fifty cocoons were measured, giving a mean length of 3.2 mm, a mean width of 2.5 mm and a mean length/width ratio of 1.2 mm. Evans and Guild (1947) have obtained similar figures for British populations. Lee (1959) records Lumbricus as feeding on dead roots and dead herbage. Waters (1955) records populations of 7.4 to 12.4 millions per ha under a perennial ryegrass/white clover pasture in New Zealand. The numbers at Hillcrest varied from 450,000 per ha in February to 5.6 millions per ha in June, with a monthly mean of 4.27 millions per ha. Newstead and Tamahere populations are similar to Hillcrest except in summer, when figures can be as low as 310,000 per ha.

Altermetaponia rubriceps (p.165)

The Australian soldier fly is a stratiomyid which has become a serious pest of pasture since 1964. It has steadily increased its numbers and distribution. Larvae when full grown at the end of the final instar measure 11 mm in length (mean for 327 larvae). The greatest numbers of larvae occur in the 3-5 cm layer below the surface, although penetration of small larvae can occur to 15 cm. Numbers vary from year to year, but a population of 2.1 millions per ha is the usual monthly mean at Hillcrest. Numbers of 5.3 millions per ha have been recorded.

Throughout the year, larvae of different instars are present. During late spring at Hillcrest, up to 58% of all larvae bigger than 8 mm in length are parasitised by a fungus. Timlin (1969) has suggested that this may be Beauveria sp. Puparia occur throughout the year within the 0-2 cm soil layer, but a peak occurs in February and another in April, when major emergence of adults occurs. No direct effects of damage by larvae have been observed by the author, but Timlin reports the adverse effects upon growth of Lolium perenne through the introduction of larvae during pot trials. Root tissues are scarcely damaged by the larvae, but growth is minimised through the removal by suction of plant juices.

Phylloxera sp. (p.164)

Only 20 specimens were found during the whole survey period, and then only at Hillcrest and Tamahere. They occur 8-10 cm below the surface attached to the roots of Trifolium repens where sap is extracted. The mean length is 10 mm with a size range of 8.3-12.9 mm. No visible adverse effects upon the plants have been observed.

Wiseana cervinata (p.164)

Occasional larvae have been found but only at Hillcrest, although adults have been observed resting on vegetation at Hillcrest and Newstead in October and November. The full grown larvae are found under litter and within the top 4 cm of soil. They have not been found under dense stands of Holcus lanatus. The mean length of 34 larvae is 5.5 cm; range 4.9-6.4 cm. No attempt is made here to estimate population numbers - insufficient specimens have been obtained - but it would seem that numbers were low during the period of survey. However, damage to roots and bases of leaves and stems can occur in pastures when large numbers of Wiseana larvae are present, as stated by a number of New Zealand authors (Cumber, 1958; Luxton, 1968).

Apatochernes proximus (p.158)

This pseudoscorpion is encountered occasionally at Hillcrest, the one figured being collected in December attached to a golden-bottle fly Calliphora erythrocephala (Meig.). Those pseudoscorpions encountered (5 in total) were found in December and January. Apart from the phoretic specimen, they were found on the surface in leaf litter. Numbers are not known for the total population or their seasonal distribution, but Beier (1966) notes that most European forms are encountered in spring and early summer - this being the population peak. The author has found in laboratory feeding experiments that Apatochernes will feed upon Entomobrya nivalis, Punctoribates punctum and dead, small enchytraeidae, but would not feed upon Staphylinidae, Araneida or triturated Lumbricus rubellus even when deprived of food for 5 days. No plant material was taken but moisture was picked up from damp surfaces.

Acarina (Punctoribates punctum, Oppia, sp., Platynothrus sculptus, Scutovertex sculptus.) (pp.158-160)

During the survey period little attempt was made to separate out the population fluctuations of individual species of Acarina. The emphasis was upon the numbers and distribution of the Acarina as a whole, with an investigation of feeding habits. The overall pattern of population fluctuation shows a summer (February/March) maximum of 2,700,000 per ha and a minimum of 620,000 in early spring (September/early October). At Hillcrest, a mean monthly population of mesostigmatids is 1.4 millions per ha, and oribatids 496,000 per ha. At Newstead and Tamahere, the mean mouthly mesostigmatid population is 2.48 millions per ha (although a population of 3.41 millions was recorded in May) and the mean monthly oribatid population is 1.5 millions per ha. Through feeding experiments in the laboratory, it was found that the oribatids Platynothrus sculptus and Scutovertex sculptus showed feeding preference for decomposing litter, particularly of soft annuals, Trifolium repens and Plantago lanceolata. Finely triturated Lumbricus rubellus was consumed, but not if vegetation was present in the feeding area. The mesostigmatids Oppia sp. and Punctoribates punctum fed upon live Collembola, other mesostigmatids (particularly young nymphs), triturated Lumbricus rubellus and whole, dead enchytraeids. In summer at all 3 sites, Acarina occur mostly in in the top 2 cm of soil, but in the winter extend to at least 6 cm below the soil surface. The majority, however (43%), occur in the 0-1 cm level.

Entomobrya nivalis (p.162)

This small Collembolan is present throughout the year at all 3 sites, but with considerable variation in population numbers. The maximum number occurred (1.72 million per ha) at Hillcrest in March 1967, just after light rain had fallen. Weis-Fogh (1948) has recorded 2.9 million per ha in Britain in a similar situation. A mean population per month has little meaning due to the intense fluctuations of numbers - if sampling is co-incident with a maximum or minimum ina fluctuation, a false picture could be created. However, it seems that at Hillcrest a minimum population (32,000 per ha) occurs in August/September. Two peaks occur - spring (November, 2,000,000 per ha) and autumn (April, 1,330,000 per ha). McMillan (1967) records Entomobrya present at his sampling site in New Zealand during all months except June, and at no time in great numbers. Ford (1937) found in Britain a winter maximum of all Collembola. MacFadyen (1962) considered that the fluctuations for all British species coincided. Milne (1962) evidenced for Britain that half-yearly maxima in summer and winter occur for all species, but concluses "this should not be considered universal for all species and habitats." At Hillcrest, the majority (67%) occur in the top 1-2 cm of soil during summer, but are distributed down to 6 cm in winter with the majority (23%) in the 0-1 cm level. Ford (1937) has found significant correlations between soil moisture content and population numbers - low numbers frequently occur when soil moisture content is low. The food of Entomobrya is not known, but Ford has suggested grass pollens and decomposing vegetation. Feeding experiments by the author were inconclusive.

Psocoptera (p.163)

The specimen figured is 4.3 mm in body length, and is probably Myopsocus novae-zelandiae. Psocids occur sporadically at all 3 sites, but never in great numbers. They occur more commonly in February, March and April, where they remain motionless on the top of leaf litter and the lower leaves of vegetation. Imms (1964, p.486) states that alate Psocids feed on fragments of vegetation, particularly fungi and unicellular algae, thus helping to contribute to the breakdown of litter. No feeding experiments have been carried out by this author.

Geophilus sp. (p.161)

Salt, Hollick, Raw and Brian (1948) have recorded in Britain 6.48 million geophilids per ha in November, and 3.34 million per ha in May. Although these figures are large, they must be regarded with caution because of the small number of samples taken (40 in total), and they were taken on two occasions only. However, the authors do place significance on the difference between the numbers at the two sampling times - it being known that Geophilus undergoes seasonal vertical migration (Ghilarov, 1962). This author has found for Hillcrest a monthly mean population of 301,000 per ha, with a June maximum of 716,000 and a minimum figure of 165,000 per ha in October. Blower (1956) states that susceptibility to desiccation is of little importance since they are able to avoid drought by burrowing deeper into the soil. Burrowing is in leaf litter, but the majority are found in the top 1-2 cm of soil. Little is known of the feeding habits of geophilomorph centipedes in New Zealand. Feeding experiments by the author in the laboratory have yielded only one positive response. In one instance with one centipede, feeding was observed on triturated Lumbricus rubellus. This could not be repeated.

Lycosa sp. (p.157)

This hunting spider lives almost exclusively in leaf litter and amongst the lower leaves of vegetation. The body length is 7 mm, with an extended leg span up to 18 mm. The monthly mean population is 56,000 per ha, with a January maximum of 238,000, and a June minimum of 10,000 per ha. Egg sacs are carried attached to the female spinnerets during September to January, and as has been observed, the newly-hatched young climb on to the dorsal side of the female.

Forster (1967) states that many Lycosidae make a silk-lined shallow burrow in the ground. This has not been observed at Hillcrest where vegetation is long, but in the short pasture at Newstead and Tamahere burrows are made in January. Feeding has been observed in the laboratory on the amphipod Orchestia sp.

Linyphiidae (Mynoglenes sp.) (p.157)

This family of spiders, although small in size, is the dominant group in pastures. At Hillcrest, a monthly mean of 112,000 per ha occurs, with a February maximum of 714,000, and a July minimum of 30,000 per ha. Bristowe (1958) records populations of 5.5 million per ha in an undisturbed Dactylis glomerata pasture in Britain. Muma and Muma (1949) record 4.2 million per ha in a prairie area.

The spiders are small, and inconspicuous in colouring. For 56 specimens at Hillcrest, the extended leg span is 12.2 mm and the mean body length 4.1 mm. In autumn and early winter the vegetation of pastures is often covered by the horizontal webs of this group. Food is most probably small flying arthropods (Bristowe). Egg sacs produced in March are yellow-brown, papery and pear-shaped, measuring 3 mm in length. Generally, the sacs are suspended by a single thread from the underside of dried plant stems. Newly-hatched spiders have a mean leg span of 4.1 mm.

<u>Forficula auricularia</u> (p.163)

This European earwig is found occasionally at Hillcrest in leaf litter, but penetrates to 2 cm in the soil in late April. Three egg clumps (mean number of eggs 27) have been observed in September, with a female curled around each clump. Young white earwigs have been recovered from the top 2 cm of soil in October and November. The author has not observed feeding, but Morris (1927) mentions Collembola and soft plant tissues (species not specified) as food in Britain. Because of low numbers occurring at Hillcrest, no attempt is made here to estimate population numbers or fluctuations.

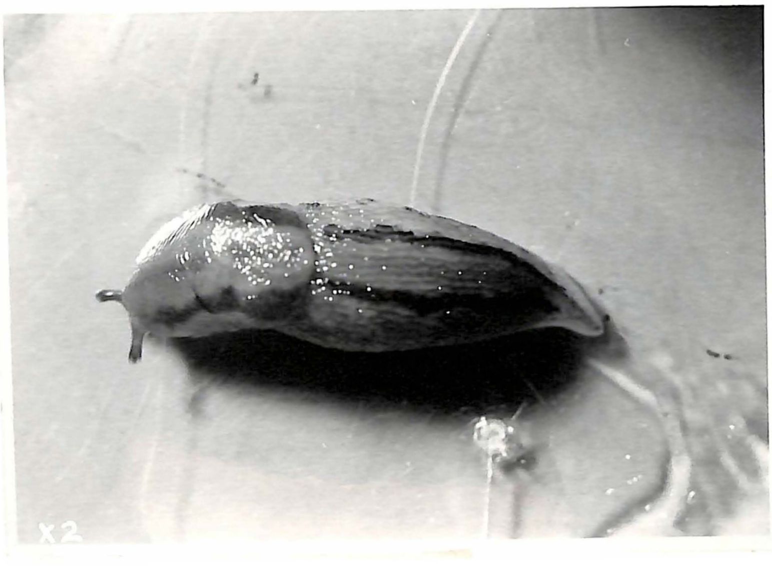
<u>Orchestia</u> sp. (p.161)

This amphipod is a litter- and surface-dweller through most of the year, but penetrates to 3 cm depth in the summer where vegetation and litter are sparse. The maximum numbers at Hillcrest occur in the 0-1 cm level of the soil. At Hillcrest, a mean monthly population of 140,000 per ha is present, with a November maximum (328,000 per ha) and a January, February and March minimum (18,000 per ha). The population numbers at Newstead and Tamahere are approximately 50% less than at Hillcrest at all times. Feeding experiments by the author in the laboratory would indicate that dead <u>Holcus lanatus</u> leaves are not eaten until partially decayed, but recently-dead leaf material of <u>Lolium perenne</u>, <u>Anthoxanthum odoratum</u> and <u>Trifolium repens</u> are eaten within 24 hours. The inter-vein tissues are consumed first, and the coarser material remaining is largely rejected until well decayed. Major feeding activity occurs at night.

ENCHYTRAEIDS

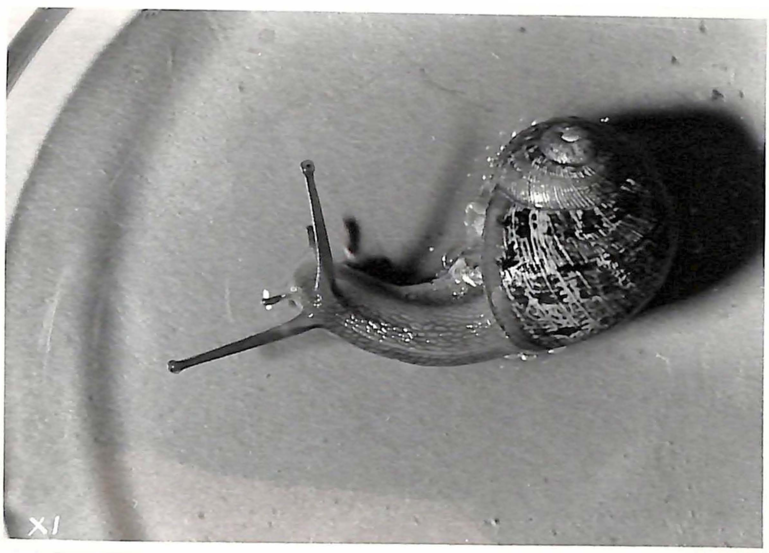
LUMBRICUS RUBEILUS

COCOONS OF ALLOLOBOPHORA CALIGINOSA



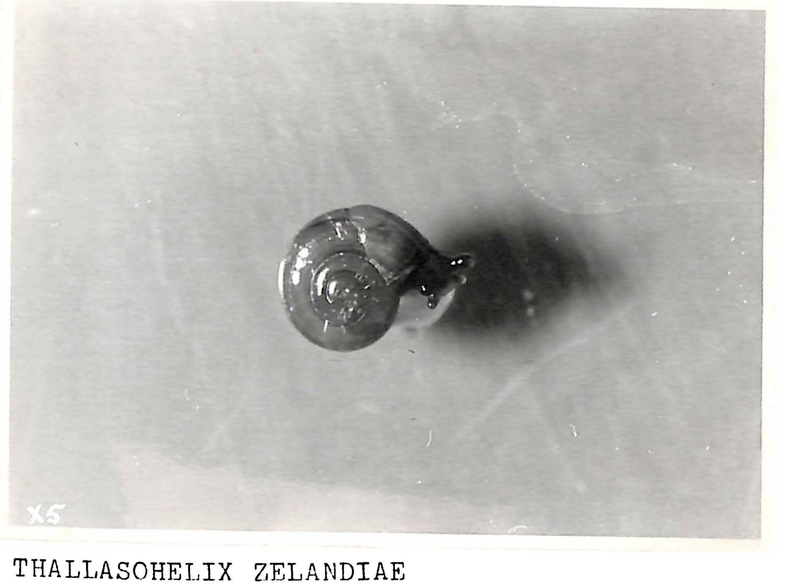
LIMAX MAXIMUS (TIGER SLUG)

AGRIOLIMAX RETICULARIS (GREY FIELD SLUG)

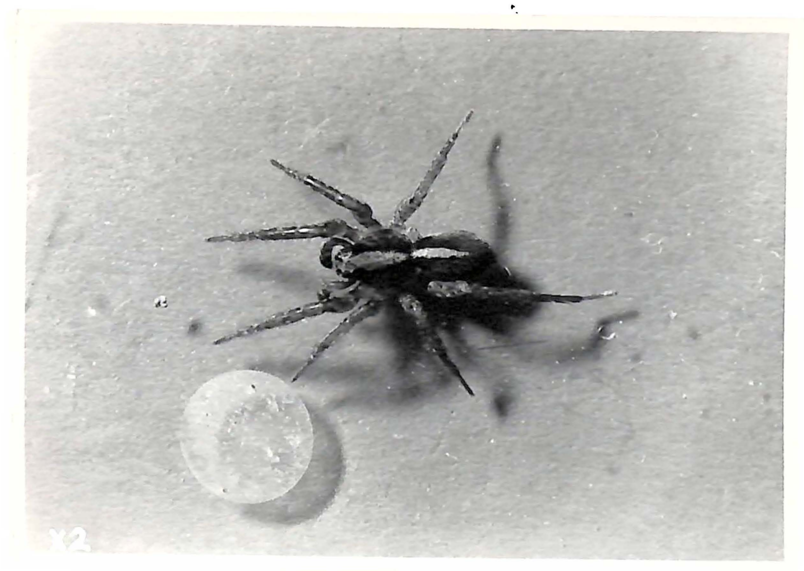


HELIX ASPERSA (COMMON GARDEN SNAIL)

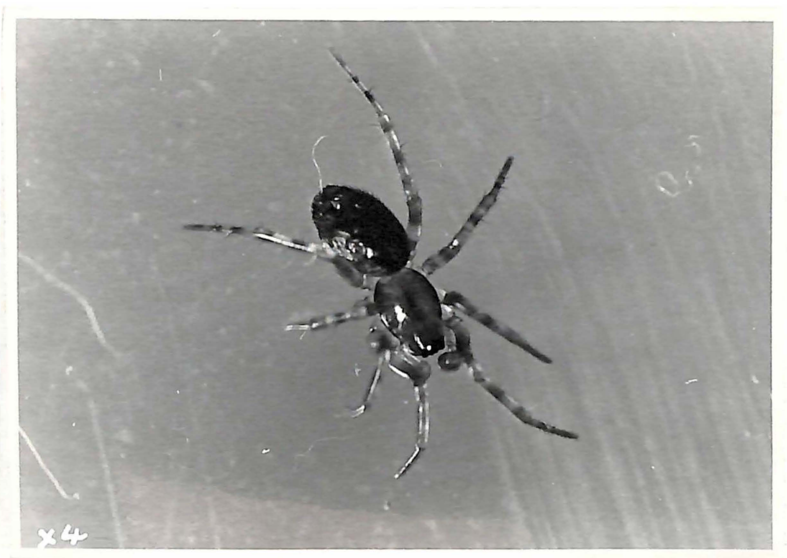
THALLASOHELIX ZELANDIAE



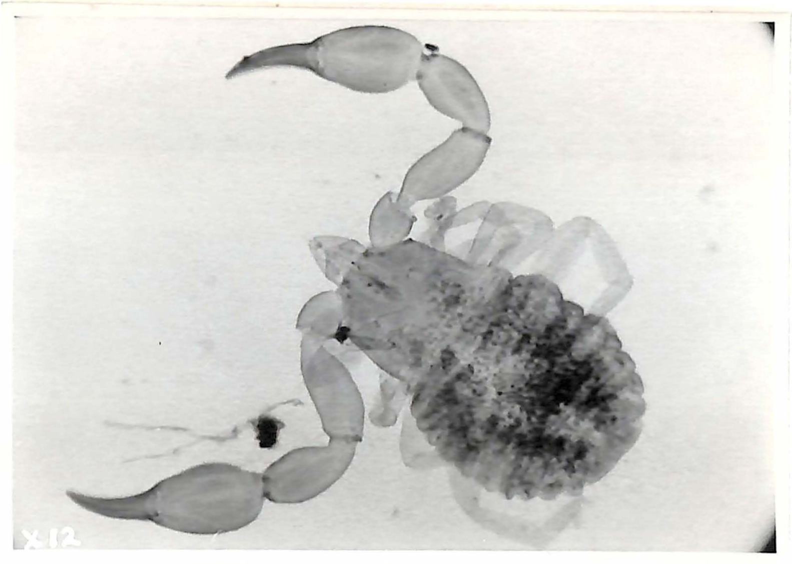
THALLASOHELIX ZELANDIAE



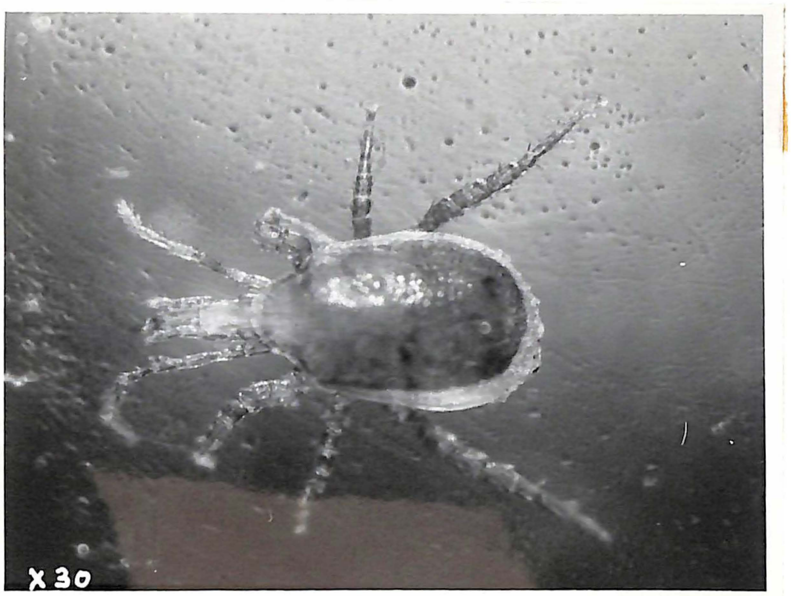
LYCOSA SP. (WOLF SPIDER)



LINYPHIID - MALE (POSSIBLY MYNOGLENES SP.)



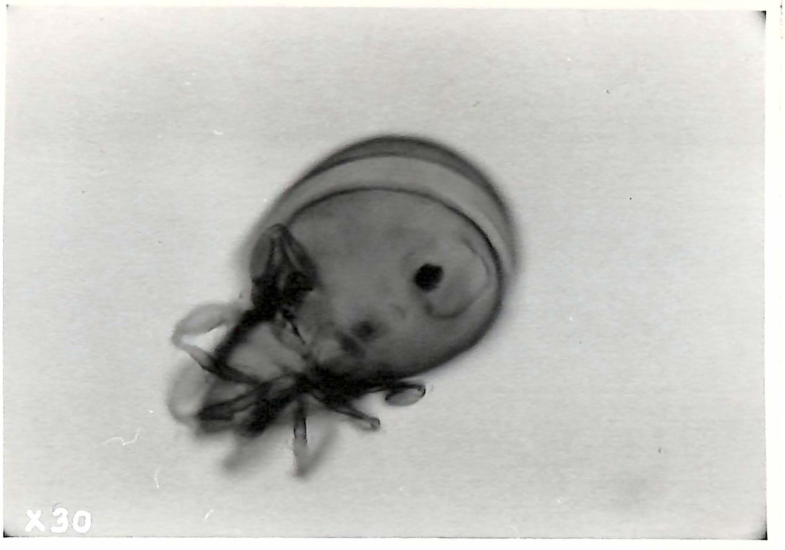
Apatochernes proximus Beier



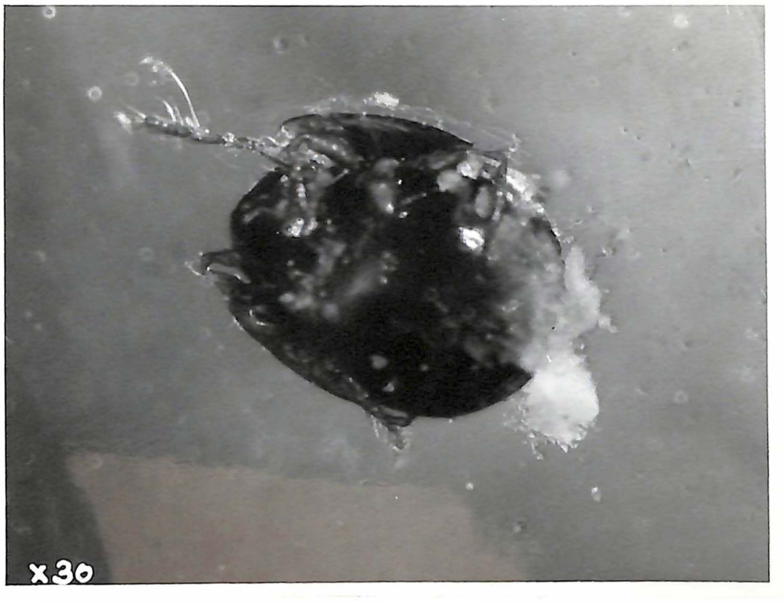
PUNCTORIBATES PUNCTUM

OPPIA SP.

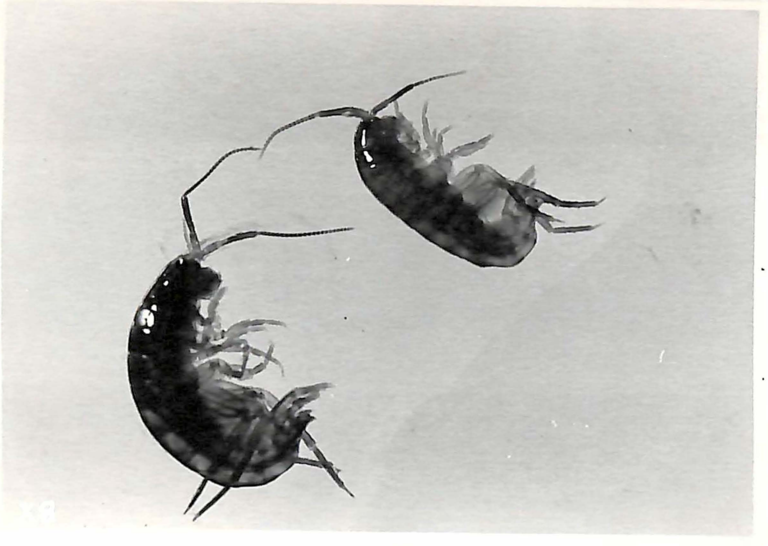
OPPIA SP. - HEAD DETAIL



PLATYNOTHRUS SCULPTUS



SCUTOVERTEX SCULPTUS

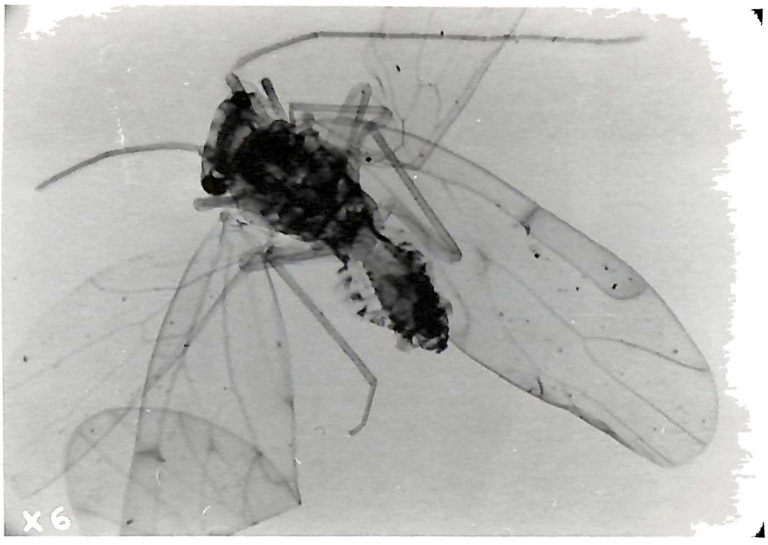


ORCHESTIA SP. (LITTER AMPHIPOD)

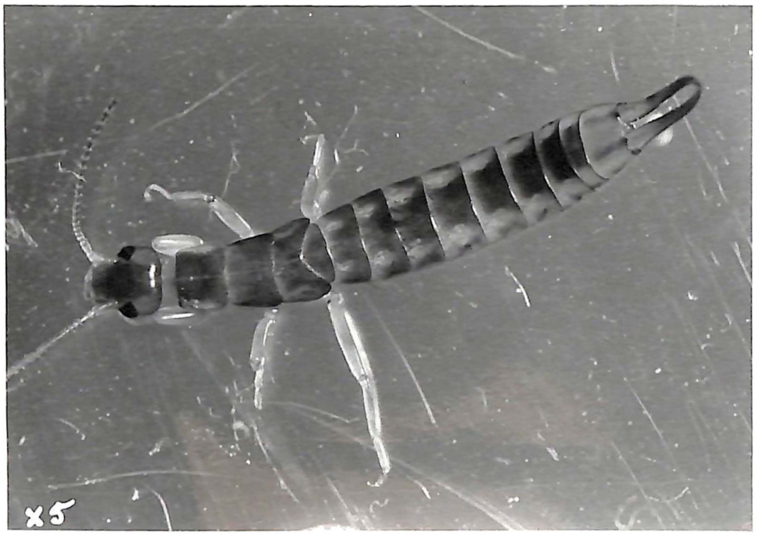
GEOPHILUS SP. (LITTER CENTIPEDE)

ENTOMOBRYA NIVALIS

ENTOMOBRYA SP.

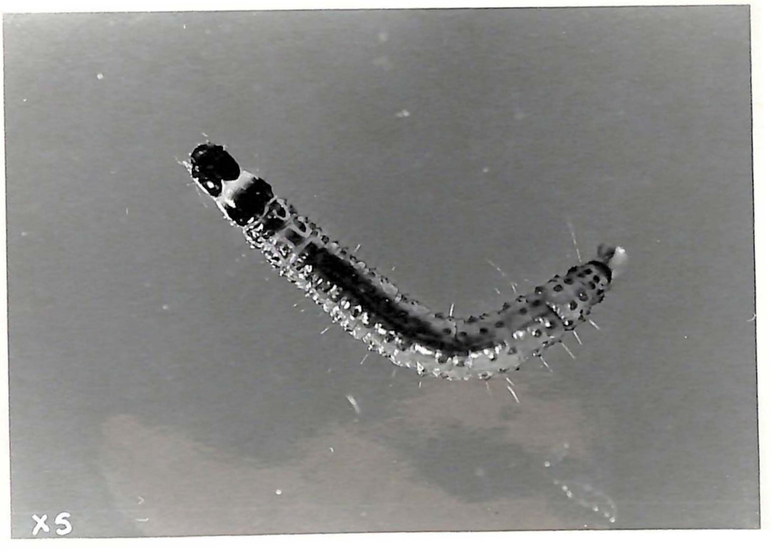


PSCOPTERAN

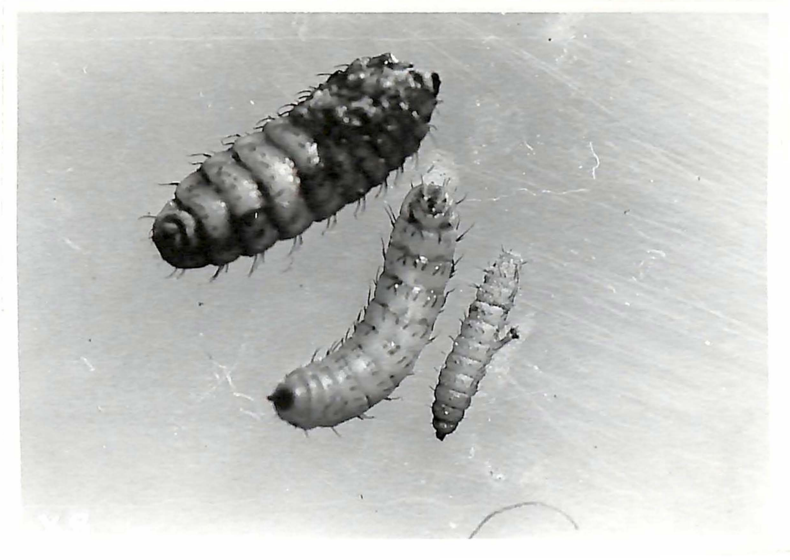


FORFICULA AURICULARIA (EUROPEAN EARWIG)

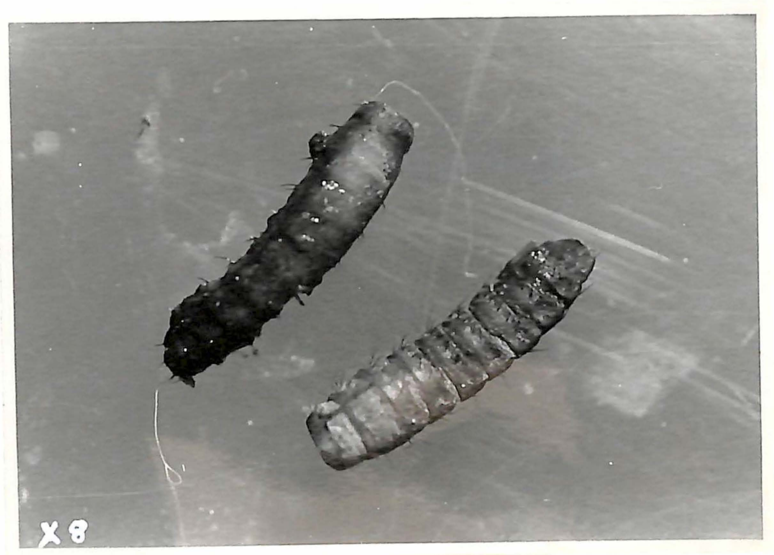
PHYLLOXERA SP.



LARVA OF WISEANA CERVINATA (PORINA)



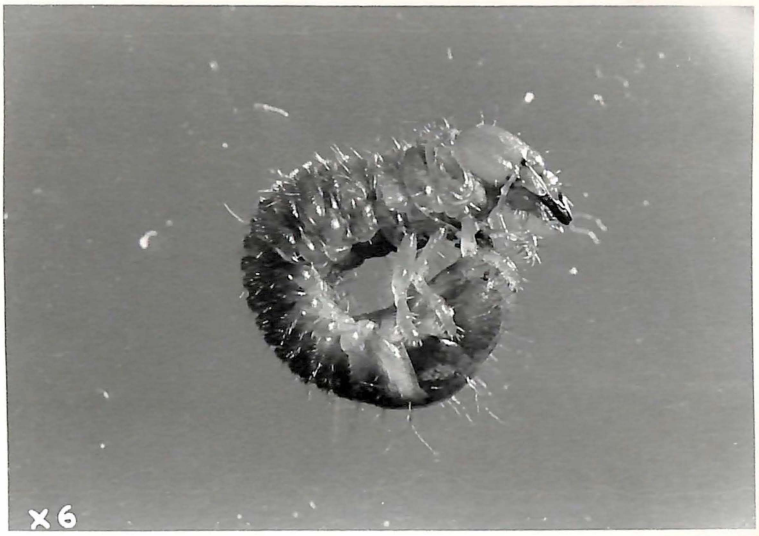
LARVAE OF ALTERMETAPONIA RUBRICEPS (SOLDIER FLY)



EMPTY CASES OF PUPARIA OF ALTERMETAPONIA RUBRICEPS

ELATERID ADULT

CARABID LARVA



LARVA OF COSTELYTRA ZEALANDICA (GRASS GRUB)

CREOPHILUS OCULATUS (ROVE BEETLE)

PHOTOGRAPHIC DETAILS OF PRINTS

Film - Kodak Tri-X Pan (ASA 400)

Subject	Comment	Frame length mm	Film-subject cm	Aperture f	Speed (seconds)
Enchytraeids	flash	18	15	9	1/60
Earthworm	50mm lens + extension x 1.5	47	23	16	1/60
Earthworm eggcases		20	15	8	¼
Agriolimax reticulatus	lens reversed	46	20.5	8	¼
grey slug	50mm lens + extension x 2	34	20	14	1/60
small snail 1	flash	13.5	15	8	1/60
small snail 2	flash	13.5	15	8	1/60
Helix aspersa	flash lens reversed	51	21	16	1/60
Lycosid	flash extension x 2	34	20	14	1/60
Lyniphiid	flash extension x 2	13	18	8	1/60
Mesostigmatid 1	x 25			22	½
Mesostigmatid 2 (head)	Kodachrome II then copied	20		5.6	1/60
Mesostigmatid 3	"			5.6	1/60
Oribatids 1	"			5.6	1/60
Oribatids 2	x 25			22	½
Pseudo - scorpions					
Orchestia		20	20	8	1/15

PHOTOGRAPHIC DETAILS OF PRINTS (cont.)

Subject	Comment	Frame length mm	Film-subject cm	Aperture f	Speed (seconds)
Centipede	flash extension x 2	19	20	12.5	1/60
Collembola 1	x 40			22	30
Collembola 2	x 40			22	30
Forficula auricularia		19	22	16	1
Pscoptera)	Kodachrome II then copied	x20		5.6	1/60
Phylloxera)		x40	22	5.6	1/60
Porina larva		19	22	5.6	¼
Altermetaporia larvae		19	22	8	¼
Altermetaporia puparia		19	22	8	¼
Elaterid	flash	16	15	11	½
Carabid larva	flash	14	15	8	½
Scarabid larva		19	22	16	1
Creophilus ochreatus	flash extension x 2	19	20	11	1/30

SECTION 12 :

A SUMMARY OF THE PASTURE PHENOLOGY OF HILLCREST

Photographs were taken during the seasonal cycle, September 1967 - August 1968

Figures given for each month are mean figures for 1967-1969

JANUARY

In January, the vegetation is past its maximum growth, the average height being around 30 cm, but clumps of vegetation stand at 80 cm in height. Litter depth is around 10 cm. This is slightly less than in December.

The flowering period of the grasses is declining, but those plants in flower include: yarrow; brown top; red top; scarlet pimpernel; lawn daisy; mouse-eared chickweed; Scotch thistle, hawksbeard; some very late Yorkshire fog; cat's ear not yet at its maximum; perennial rye; Lotus uliginosa; pennyroyal just starting to flower; creeping mallow reaching its maximum; Paspalum dilatatum almost at its maximum flowering; Paspalum paspaloides flowering only slowly; narrow-leaved plantain at its maximum; broad-leaved plantain continuing, but not at its maximum; selfheal; creeping buttercup; dock; black nightshade beginning flowering in January; Onehunga weed at its maximum; dandelion; white clover and speedwell.

Slugs attain their maximum numbers in early January accompanied by an egg-laying period which is less than that of the May and June season. Lumbricidae and Enchytraeidae are most numerous 16 cm below the surface. At the surface, however, their numbers drop considerably. The dominant groups of animals in the January period are the Acarina, Collembola and Stratiomyidae.

The mean aid temperature 61.0 cm above the ground is 20.3°C, the mean maximum, 23.6° and the mean minimum, 17.0°. The highest temperature can reach 31.5° and the minimum may be 6.0°. However, only on 61% of the days in January may the temperature exceed the mean maximum, but on 87% of the days the temperature falls below the mean minimum.

At the soil-vegetation interface the mean temperature is 19.9°, the mean maximum 22.4°, and the mean minimum 17.2°. The temperature may rise to 26.0° or drop to 11.0°. On 45% of the days the temperature may exceed the mean maximum and on 19.4% it may drop below the mean minimum.

16.5 cm below the surface the mean temperature for January is 20.2°, the mean maximum 21.2°, the mean minimum 18.7°. Temperatures may reach 24.0° and drop to 16.0°. On 41.9% of the days in January the mean maximum temperature may be exceeded, but 35.5% of the days the temperature may drop below the mean minimum.

On 22.6% of the days in January there will be rainfall, averaging 39.4 mm for the month.

The mean RH is 70.6%, but every day in January the RH will drop below this mean. In the top 16.5 cm of soil the soil moisture percentage is 78.4.

Briefly, the picture which presents itself in January is one of slowed growth compared to the previous two months. The moisture-preferring animal groups seek greater shelter in moist conditions below or within the litter layer. The temperatures (air, interface and soil) do not fluctuate greatly during the month.

JANUARY

FEBRUARY

In February the slowing in growth which was apparent in January continues. The average height of vegetation is 26 cm, clumps may be 65 cm, and litter 8 cm.

Grasses continue to flower, some sporadically, but by the end of February most grasses have ceased flowering. Those plants in flower include: yarrow still fully in flower; red top; brown top (sporadic); scarlet pimpernel; lawn daisy; mouse-eared chickweed; Scotch thistle; hawksbeard; Yorkshire fog; cat's ear again at its maximum; perennial rye dropping away considerably in its flowering; Lotus iliginosa declining compared with January; pennyroyal not yet at its maximum but reaching it towards the end of February and the beginning of March; creeping mallow declining; Paspalum dilatatum reaching its maximum; Paspalum paspaloides continuing and reaching its maximum after the end of February; narrow-leaved plantain; broad-leaved plantain continuing; annual Poa; selfheal; creeping buttercup declining; dock dying away towards the end of the month; black nightshade increasing but not yet at its maximum; Onehunga weed dropping away markedly towards the end of February; dandelion; white clover; speedwell ceasing at the end of February.

As soil moisture becomes less in the top soil, the total number of animals continues to decline in this layer compared with January. Still numerous, however, are the Acarina, Collembola, and Stratiomyidae. The Araneida show a decline in numbers to two-thirds of the January level.

The mean air temperature 61.0 cm above the ground is 20.6°, warmer than in January. The mean maximum is 23.6°, the mean minimum 16.5°. Maximum temperatures may rise to 30.0° and minimum temperatures fall to 6.0°. On 86% of the days in February the temperature may rise above the mean maximum, and on 82% of the days the temperature may fall below the mean minimum.

The mean temperature of the interface is 19.0°, with the mean maximum 20.7° and mean minimum 18.0°. Temperatures may rise to 26.0° and fall to 12.0°. On 71.4% of the days in February the temperature may rise above the mean maximum. On 50% of the days it may drop below the mean minimum.

16.5 cm below the soil surface, the mean temperature is 19.5°, the mean maximum is 21.6°, the mean minimum 16.1°. The temperature may rise to 23.0° or fall to 16.0°. On 17.9% of the days the temperature may exceed the mean maximum, but on only 3.6% of the days will the temperature fall below the mean minimum.

21.4% of the days will have rainfall. This averages 34.4 mm for the month.

The RH mean is 76.0%. 92.9% of the days the RH may drop below the mean. The soil moisture in the top 16.5 cm averages 72.0%.

In summary, February is slightly warmer than January; slightly drier, and the RH will be higher particularly in the mornings. The growth of vegetation has slowed and the number of animals that are present in the top layers of the soil is considerably less than the January totals but still the greatest numbers of animals are found within three major groups.


FEBRUARY

MARCH

During March the growth of summer and autumn slows almost to a final halt. The average height of vegetation is 22 cm, some clumps reading 62 cm, and litter to 8 cm in depth.

Plants in flower include: yarrow (similar to February); red top and brown top diminishing; scarlet pimpernel ceasing by the middle of the month; lawn daisy slowing considerably compared with February; mouse-eared chickweed continuing sporadically, hawks-beard; Yorkshire fog ceasing shortly after the beginning of the month; cat's ear declining considerably compared with February; perennial rye flowering sporadically; Lotus uliginosa ceasing by the end of March; pennyroyal in the middle of its flowering season; creeping mallow declining and ending in the last few weeks of March; Paspalum dilatatum not so strongly as in February; Paspalum paspaloides reaching its maximum by the end of March; narrow-leaved plantain and broad-leaved plantain continuing but with a steady decline; selfheal and creeping buttercup and dock much less than in February and declining further as the colder weather sets in; black nightshade increasing reaching its maximum at the end of March; Onehunga weed declining; dandelion continuing strongly; white clover declining to half its former February level by the end of March.

The total fauna shows a steady upward increase in numbers. Lumbricidae increase as to Enchytraeidae and Collembola.

The air temperature 61.0 cm above the surface has a mean of 22.0°, and the mean maximum is 25.1°, which is higher than in February. The mean minimum is 18.9°. Temperatures may reach a maximum of 25.1° and a minimum of 8.0°. 77.4% of the time the mean maximum is exceeded and 87.1% of the time temperatures drop below the mean minimum.

At the interface the mean temperature is 20.2°, the mean maximum 22.9° and the mean minimum 17.4°. Maximum temperatures of 25.0° and minimum temperatures of 11.0° may be reached. 61.2% of the days in March may exceed the mean maximum and 38.7% of the days the temperature may drop below the mean minimum.

16.5 cm below the surface the mean temperature is 20.6°. Mean maximum is 21.7° and the mean minimum 19.1°. Maximum temperatures may reach 23.0° and minimum temperatures 16.0°. On 64.5% of the days in March the mean maximum may be exceeded and on 22.6% of the days the temperature may drop below the mean minimum.

35.5% of the days will have rain, the precipitation being 31.3 mm for March.

During March the RH is 76.1%; on 80.6% of the days the RH will drop below this figure. In the top soil, the soil moisture will average 86.0%.

In summary, March is a time when the great heat of February is still present, but temperatures are fluctuating a great deal more than in February. Although rainfall is very similar in March and February, the precipitation is spread more evenly throughout the month, with the result that soil moisture percentage starts to increase. The number of animals in the soil increases slowly above the February levels, but consists of the three major groups, Acarina, Collembola and Lumbricidae. Most plant groups have completed their flowering, although some, such as Paspalum paspaloides, do not reach their maximum until the end of the month.

MARCH

APRIL

In April, vegetation has practically ceased its growth. The mean height of vegetation is 28 cm, although some clumps can rise to 60.0 cm. Leaf litter averages 7 cm.

Plants in flower include : yarrow at the same level as March; red top; brown top declining and finishing by the end of the month; lawn daisy finishing by the middle of the month; mouse-eared chickweed (sporadic); hawksbeard continuing at the March level; cat's ear slowly declining; perennial rye slowing and stopping by the end of April; pennyroyal continuing but at half the March level; Paspalum dilatatum stopping by the end of April; Paspalum paspaloides steadily declining; narrow-leaved plantain declining and ceasing at the end of the month; broad-leaved plantain increasing slightly towards the end of the month but not up to the maximum of the February level; selfheal and creeping buttercup continuing but to a lesser degree; dock finishing early in April; black nightshade declining; Onehunga weed ceasing by the middle of the month; dandelion and white clover decreasing.

The total number of animals in the top soil and interface shows a slight increase over the March maximum. Groups which have increased are: Collembola, Acarina; Lumbricidae, Stratiomyidae and Enchytraeidae. There are decreasing numbers of: Staphylinidae, Formicidae and Araneidae. Mollusca begin their second breeding period, but the maximum is not reached till the end of April.

61.0 cm above the ground the mean air temperature is 15.6°, the mean maximum 17.5° and mean minimum 13.6°. Temperatures may reach a maximum of 25.0° and minimum of 3.0°. 66.7% of the days the mean maximum may be exceeded and 66.7% of the days the temperature may drop below the mean minimum.

At the interface, the mean temperature is 15.3°, the mean maximum is 17.4°, the mean minimum 15.4°. Maximum temperatures may reach 22.0° and minimum temperatures may be 8.0°. On 36.7% of the days in April, the temperature will exceed the mean maximum, but 93.3% of the days the temperature will fall below the mean minimum.

16.5 cm below the soil surface, the mean temperature is 16.5°, the mean maximum 16.9° and the mean minimum 15.5°. The temperature may rise to 21.5° or fall to 12.0°. 46.7% of the days in April, the temperature may rise above the mean maximum, and 43.3% of the days may fall below the mean minimum.

66.7% of the days there will be rain, precipitation measuring 200.3 mm.

The average RH is 81.8%; 76.7% of the days in April the RH will drop below this mean. The soil moisture in the top 16.5 cm averages 94.10%.

In summary, April is a time when temperatures are dropping rapidly. No frosts are yet expected, but the minimum temperature is only several degrees above freezing point. A greater number of days with rain can be expected and the total precipitation greatly exceeds that expected in March, resulting in a much higher RH in the air and a vastly increased soil moisture in the top soil. With the decrease in temperature and the marked contrast between day and night-time temperatures, as well as the decrease in number of daylight hours, the growth of plants has stopped, although one or two of the grasses have reached their maximum flowering at this time. Surface-dwelling animals have decreased in numbers, but litter-dwellers and those in the top 16.5 cm of the soil continue to increase in numbers.


APRIL

MAY

In this final month of autumn, the height of vegetation continues to decrease, averaging 22.0 cm. Some clumps, however, may reach 60 cm. Depth of leaf litter is 5 cm.

Those plants continuing to flower include: yarrow, although the total amount of flowering has diminished; mouse-eared chickweed (sporadic); hawksbeard now declining; cat's ear declining until the end of May when all except a few plants have finished; pennyroyal past its maximum but continuing steadily through to the end of May; Paspalum paspaloides slowly declining and finishing at the end of May; a few plants of broad-leaved plantain which finish by the end of the month; some selfheal; some creeping buttercup (this is the minimal flowering period for buttercup); black nightshade beginning to decline; dandelion continuing but not as strongly as in April; and white clover continuing but below the April level.

The total fauna increases above the numbers found in April, but surface-dwellers decline in numbers. The biggest increase is in the Collembola and Mollusca, while the Acarina decline in numbers compared with the previous month.

61.0 cm above the ground the mean temperature in May is 12.7°, the mean maximum 15.2° and the mean minimum 10.2°. The maximum temperature may rise to 21.0° and the minimum temperature may drop to 0.0°. On 77.4% of the days in May the temperature may rise above the mean maximum and on 67.7% of the days the temperature may drop below the mean minimum. Frosts may be expected on 3.2% of the days in May.

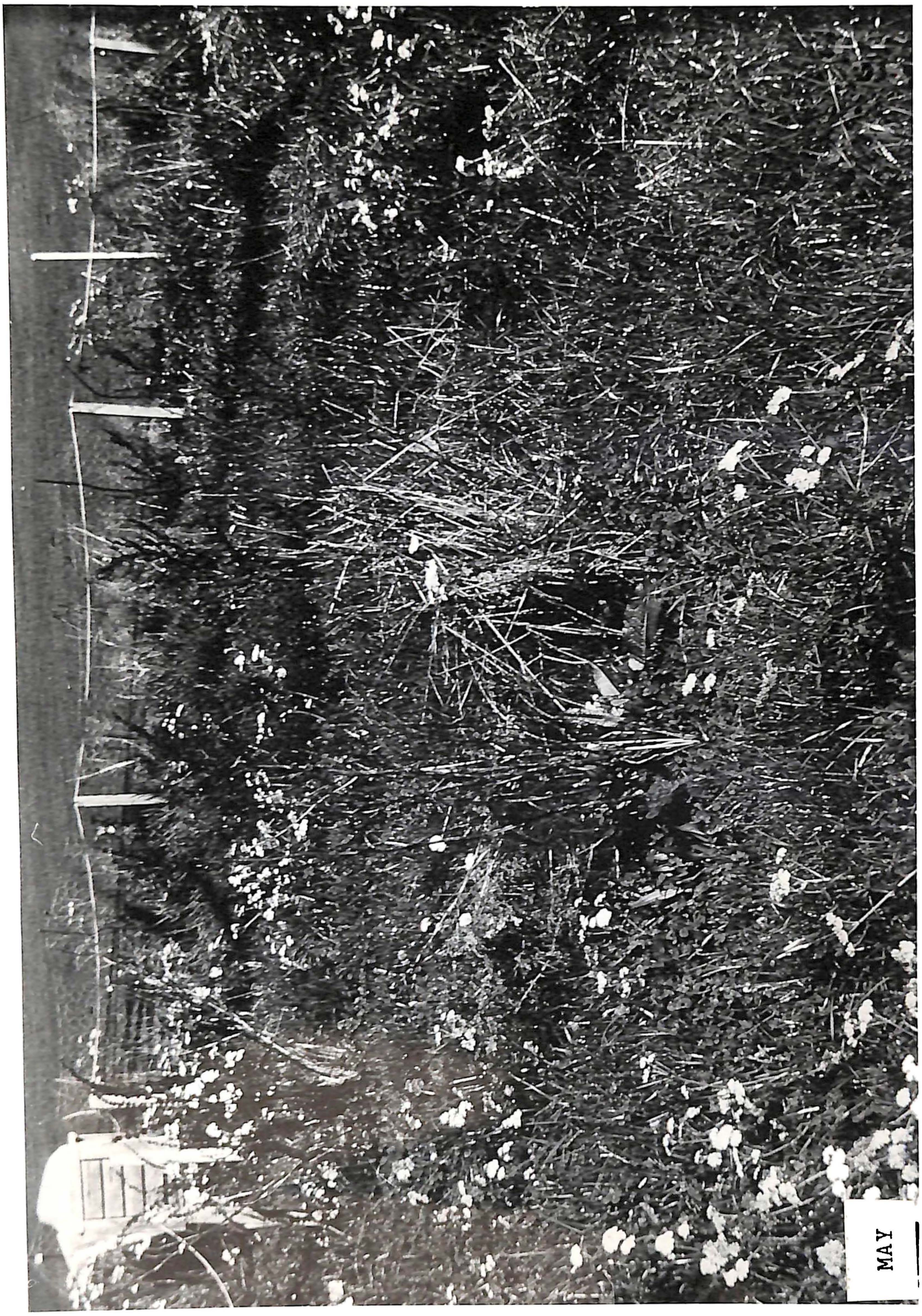
At the interface, the mean temperature is 12.0°, the mean maximum 14.4°, and the mean minimum 9.3°. Temperatures may rise to 19.0° or fall to 3.0°. On 41.9% of the days in May, the temperatures may rise above the mean maximum and on 32.3% of the days the temperature may fall below the mean minimum.

16.5 cm below the soil surface, the mean temperature is 13.3°, mean maximum 14.0° and mean minimum 12.0°. Temperatures may rise to 18.0° and fall to 3.0°. On 32.3% of the days in May, the temperature may rise above the mean maximum and on 38.7% of the days may drop below the mean minimum.

64.5% of the days will have precipitation, average for May being 186.0 mm.

The mean RH is 86.7%, but 64.5% of the days in May the humidity may fall below this mean. In the top soil the moisture averages 97.10%.

In summary, the May period marks the beginning of the cessation of plant and animal growth, the majority of plants have ceased to flower, surface-dwelling animals have dropped considerably in numbers, but where the fauna is protected below the litter layer, the numbers continue to rise, the Collembola increasing noticeably. In the last two weeks of May frosts occur, and these, together with the increased rainfall and lower temperatures mark the beginning of winter.


MAY

JUNE

Plant growth is at its minimum for the year during the month of June. Average vegetation height is 19 cm; clumps of vegetation may reach 40 cm, and litter 4 cm.

The majority of pasture plants have completed their flowering. Those plants in flower include: yarrow (although the flowering of yarrow continues through June the total numbers are less than in May); lawn daisy (sporadic); mouse-eared chickweed (sporadic); a few plants of hawksbeard and cat's ear continuing but finishing by the middle of June; pennyroyal and selfheal also ceasing by the middle of June; creeping buttercup at its minimum at this time, but increasing to half the maximum level at the end of the month; black nightshade and white clover continuing but finishing by the end of June.

The fauna reaches its maximum numbers at the beginning of June but declines rapidly towards the end of the month. Mollusca deposit their final batch of eggs at the beginning of June. The greatest numbers of animals occur among the litter-dwelling Collembola; all other groups show a marked decline in numbers.

61.0 cm above the ground surface the mean temperature is 10.5°, the mean maximum 12.4°, mean minimum 8.6°. The temperature may rise to 18.0° or drop to -3.0°. On 71.0% of the days in June the temperature will rise above the mean maximum during the day and on 58.1% of the days the temperature will drop below the mean minimum. Frosts can be expected on 9.7% of the days.

The temperature at the interface is 10.0°, the mean maximum 12.7°, the mean minimum 7.6°. Temperatures may rise to 18.0° and drop to -1.0°. On 67.7% of the days the temperature may rise above the mean maximum, and on 35.5% of the days will drop below the mean minimum.

In the top soil the mean temperature is 11.2°, that is, greater than the mean temperature for the air or for the interface. The mean maximum is 11.8°, the mean minimum 10.3°. Temperatures may rise to 14.0° and drop to 5.0°. On 64.5% of the days the mean maximum may be exceeded, and on 29.0% the temperature will drop below the mean minimum.

71.0% of the days will have rain, the monthly average being 161.0 mm.

The mean RH is 87.1%, but on 74.2% of the days in June the RH will drop below the mean. Soil moisture content in the top 16.5 cm is 100.00%.

In summary, June is a cold, wet month. The mean air temperature for June approximates the mean minimum air temperature for May. Frosts are frequent; the RH is high and the top soil is at its saturation point. Most plants have ceased flowering and the total fauna is declining, except for the Collembola living in the litter.

JUNE

JULY

The first half of July is very similar to the last part of June, that is, cold and damp, with precipitation expected on many days, but towards the end of July temperatures start to rise and there is a consequent regrowth of the winter vegetation. The average height of vegetation is 25 cm; clumps may rise to 45 cm. The litter depth averages 6 cm.

Yarrow continues to flower but the flowering declines towards the end of the month. Lawn daisy is at a minimum but increases again towards the end of the month. The last flowering of mouse-eared chickweed occurs and does not occur beyond the end of the month. Creeping buttercup slowly declines, dandelion flowers sporadically, speedwell begins its flowering towards the end of July.

Total faunal numbers continue to decrease, but numbers of litter-dwelling Collembola remain high and Acarina steady their numbers. Lumbricidae begin depositing their cocoons in the top soil towards the end of the month.

61.0 cm above the ground the mean air temperature is 9.0°. This is the lowest mean air temperature for any month through the year. The mean maximum is 11.6°, the mean minimum 6.5°, although a maximum temperature of 17.0° may be reached, and the temperature may drop to -3.0°. On 53.3% of the days in July the temperature will exceed the mean maximum and on 66.7% of the days the temperature will drop below the mean minimum. Frosts may be expected on 26.7% of the days in July.

At the interface the mean temperature is 8.0°, again the lowest mean interface temperature for the year. The mean maximum is 11.7° and the mean minimum 4.4°, although temperatures may rise to 17.0° and fall to -3.0°. On 46.7% of the days the temperature may exceed the mean maximum and on 66.7% the temperature may drop below the mean minimum.

In the top soil the mean temperature is 9.2°; the mean maximum 10.3°; the mean minimum 7.7°. The maximum temperature may rise to 14.0° or drop to 4.0°. On 36.7% of the days the temperature may exceed the mean maximum and on 14.0% of the days it may drop below the mean minimum.

Rainfall occurs on 50.0% of the days, giving 156.5 mm of rain for the month.

The RH is 81.2% but on 86.7% of the days the RH may drop below this. Soil moisture in the top 16.5 cm is 100.00%.

In summary, July is the coldest month of the year, but there is less precipitation on a lower percentage of days than in June. The frequency of frost is at its maximum for the year. Except for six plant groups, all species have completed their flowering and growth is at its minimum for the year. Faunal numbers are past their maximum and are starting to decline, and although some groups have started to produce eggs, the rate of production is slow.


JULY

AUGUST

During August the spring growth of vegetation begins, at first slowly but with increasing rapidity. The height of vegetation is 35 cm, clumps reaching to 72 cm; litter depth, however, remains at 4 cm.

Sporadic flowering of yarrow slows even further towards the end of August, but lawn daisy begins to flower. The occasional plant of Yorkshire fog begins to flower, and creeping buttercup completes its flowering by the middle of the month. Chickweed starts to flower at a minimal level in the last two weeks of August; speedwell continues to flower but in minimum quantities. The flowering of dandelions declines, reaching its lowest point for the year at the end of August.

Faunal numbers continue to decline; the numbers of litter-dwelling Collembola drop away rapidly towards the end of August, but by contrast the Acarina increase in number; Lumbricidae continue to deposit their cocoons; all other groups show a steady decline in numbers.

Air temperatures 61.0 cm above the surface are very similar to those of June, that is, mean temperature 10.7°, mean maximum 12.9°, mean minimum 8.5°. Temperatures may rise to 18.0° and reach a minimum of -3.0°. On 64.5% of the days in August the temperature may rise above the mean maximum and on 77.4% of the days may fall below the mean minimum. Frosts may be expected on 16.1% of the days in August, that is, 10% less than in July.

At the interface, temperatures are higher than in July and slightly higher than in June. The mean temperature is 10.4°, mean maximum 13.4°, mean minimum 7.5°. Temperatures may rise to 16.0° and fall to 1.0°. On 41.9% of the days in August the mean maximum temperature may be exceeded, and temperatures may fall below the mean minimum temperature on 38.7% of the days.

In the top soil the mean temperature is 10.9°, the mean maximum 11.9°, the mean minimum 9.5°. The temperature may rise to 13.0° or fall to 6.0°. On 71.0% of the days the mean maximum temperature may be exceeded, but may fall below the mean minimum on 38.7% of the days.

Rainfall may be expected on 58.1% of the days, but the precipitation, 123.4 mm, is less than in July.

The RH is 81.5%, but on 74.2% of the days the RH may drop below this. The soil moisture in the top 16.5 cm is 98.5%.

In summary, although temperatures are still low and frosts are frequent, the mean maximum temperatures at the interface litter area are higher than those of the soil. Most plant groups have ceased flowering, although some have already begun their spring flowering. Increase in vegetation height is noticed towards the end of August and the number of Acarina increases.


AUGUST

S E P T E M B E R

The growth of vegetation that has begun at the end of August continues in September. Vegetation height averages 45 cm, clumps may reach 70 cm, but litter is at its minimum for the year, 3.5 cm.

Yarrow completes its flowering and stops completely by the end of the month; lawn daisy continues to increase, coming into its maximum flowering at the end of September; occasional plants of Yorkshire fog come into flower; creeping buttercup recovers from its late August flowering cessation and continues to increase in total flowering. Similarly, chickweed, dandelion and speedwell increase, coming to their spring maxima at the end of the month.

The total numbers of fauna continue to decline, reaching the minimum at the end of September and beginning of October. The numbers of Mollusca remain steady and towards the end of September egg-laying begins. The numbers of Acarina and Araneida rise at the beginning of the month and continue to the end. In the top soil, the number of scarab larvae begins to decrease, with the emergence of adults in late September. Elaterid larvae begin to increase, as do adult Staphylinidae. Lumbricidae continue to deposit their cocoons, the number of Enchytraeidae increases, the number of surface-dwelling ants declines and the number of Collembola decrease at the beginning of the month, but show a slight up-surge towards the end of September.

61.0 cm above the ground the mean air temperature is 11.2°, the mean maximum 13.5°, the mean minimum 8.7°. The temperature may rise to 19.0° or fall to -1.0°. On 76.7% of the days in September the mean maximum will be exceeded and on 76.7% of the days the temperature will drop below the mean minimum. Frosts will occur on 9.9% of the days in September.

At the interface the mean temperature is 11.0°, the mean maximum 13.9°, the mean minimum 8.5°. Temperatures may rise to 17.0° and fall to 4.0°. On 63.3% of the days the mean maximum will be exceeded, and on 50.0% of the days the temperature may fall below the mean minimum.

In the top soil the mean temperature is 11.6°, mean maximum 12.5°, mean minimum 10.3°. The temperature may rise to 15.0° and fall to 8.0°. On 50.0% of the days the mean maximum temperature will be exceeded, and on 30.0% of the days the temperature will drop below the mean minimum.

60.0% of the days will have rainfall, but this will total 97.6 mm.

The mean RH will be 78.2%, but on 76.7% of the days the RH will fall below this mean. In the top 16.5 cm of the soil the moisture will be 98.5%.

In summary, the mean temperatures of the air, the interface and the soil have risen above the August levels. There are many days of rain, but the total precipitation is less than in the previous two months. The RH has dropped, but the soil moisture content still remains high. Growth of plants is slow, the total number of animals is not yet at its minimum, but at the end of the month the numbers of many groups show a marked downward turn.

SEPTEMBER

OCTOBER

The growth of vegetation, begun in August and continued in September, reaches its maximum at the end of October. Mean vegetation height is 69.0 cm, clumps may reach 92.0 cm; litter depth averages 8.0 cm.

Flowering begins for red top; brown top; sweet vernal; lawn daisy is at its maximum flowering; mouse-eared chickweed rises to its maximum at the end of October; cocksfoot, Yorkshire fog and Poa begin their growth. Narrow-leaved plantain starts its flowering, as does creeping buttercup, rising to its maximum in late October. Onehunga weed flowers dramatically. Chickweed reaches its maximum flowering. Dandelion reaches its spring maximum but declines towards the end of October. Speedwell reaches its maximum flowering, and white clover increases towards the end of the month.

At the beginning of October the total numbers of animals reaches the minimum for the year, but, within two weeks, the increase in numbers is extremely rapid. The numbers of Mollusca increase to a maximum, also the deposition of their eggs. Acarina and Araneida increase, as do the surface-dwelling animals, e.g., Staphylinidae, adult Scarabidae emerge, there is an increase in the number of Chilopoda, the Lumbricidae deposit their maximum number of cocoons, the Enchytraeidae show an increase, as do adult Carabidae and Stratiomyidae. Collembola maintain steady increase in numbers with the maximum increase towards the end of the month.

61.0 cm above the surface the mean air temperature is 13.2^{o}, the mean maximum 15.2^{o}, the mean minimum 11.2^{o}. Temperatures may rise to 22.0^{o} and fall to 1.0^{o}. On 71.0% of the days in October the temperature will rise above the mean maximum and 54.8% of the days will fall below the mean minimum. The likelihood of frosts is over.

At the interface the mean temperature is 12.8°, the mean maximum 14.7°, the mean minimum 11.1°. Temperatures may rise to 18.0° and fall to 7.0°. On 71.0% of the days the mean maximum temperature will be exceeded and the temperature will fall below the mean minimum on 32.3% of the days.

In the top soil the mean temperature is 13.4°, the mean maximum 14.1°, mean minimum 12.3°. Temperatures may rise to 16.0° and fall to 10.0°. On 48.4% of the days the temperature will exceed the mean maximum, on 32.3% of the days will fall below the mean minimum.

51.6% of the days will have rain, giving 96.8 mm for the month.

The mean RH is 75.3%, but on 83.9% of the days the RH will be below the mean. In the top 16.5 cm of the soil the moisture is 92.00%.

In summary, the growth of vegetation and the increase in temperatures which began in September continues. The likelihood of frosts is low. The soil at the interface warms rapidly, and although the amount of precipitation is similar to the previous months, the percentage of days on which rain can be expected is considerably less. The soil moisture in the top soil has become less than in the previous month.


OCTOBER

NOVEMBER

By the middle of November the main period of spring growth is past in the plants of the area. The mean vegetation height is 57 cm, the average height of clumps is 90 cm, but the mean depth of litter is 11.0 cm, reaching its maximum for the year.

Yarrow has begun its flowering; red top and brown top are into their maximum growth; scarlet pimpernel begins at the beginning of the month to reach its maximum near the end. Sweet vernal has passed its maximum by the middle of November, and lawn daisies continue to grow but with less flowering than in October. Prairie grass begins to flower in the last two weeks of November, mouse-eared chickweed shows a decline in flowering, hawksbeard begins to come up to its maximum near the end of the month. Cocksfoot is in full flower. Yorkshire fog shows a slight decline towards the end of the month, although this is its maximum month of flowering. Cat's ear comes into flower in the last two weeks of November and increases towards the beginning of December. Perennial ryegrass reaches its maximum at the end of November; narrow-leaved plantain continues to flower, reaching its maximum in late November and the beginning of December; Poa reaches its maximum in late November. Creeping buttercup continues in full flower. Dock plants increase their flowering, but do not reach their maximum until late December. Onehunga weed increases in its flowering, but chickweed declines towards the end of November. Dandelion decreases to half of the maximum flowering which occurred in October. White clover increases its flowering to reach its maximum at the end of November, while speedwell slowly declines to come to its minimum at the end of the month.

A rapid increase of numbers in the total fauna occurs and by the beginning of the third week of November the total numbers are approximately twice the minimum number which occurred in October. All groups show a marked increase. Mollusca have completed their egg laying. Acarina increase, as do Araneida. Staphylinidae increase, adult Scarabidae continue to emerge from the ground. Chilopoda maintain steady numbers. Lumbricidae continue depositing their cocoons, but in smaller numbers than in October. Enchytraeidae show an increase, as do Collembola, Carabidae and adult Stratiomyidae.

61.0 cm above the ground the mean temperature is 16.2°, the mean maximum 18.9°, the mean minimum 13.4°. Temperatures may reach 29.0° and fall to 3.0°. On 50.0% of the days the mean maximum may be exceeded, but on 86.7% of the days the temperature will fall below the mean minimum. There are no frosts.

At the interface the mean temperature is 15.9°, mean maximum 18.4°, mean minimum 13.6°. Temperatures may reach 23.0° or fall to 11.0°. On 43.3% of the days in November the mean maximum may be exceeded, and on 43.3% of the days the temperature may fall below the mean minimum.

In the top soil the temperature is 16.0°, the mean maximum 16.9°, the mean minimum 14.6°. The maximum temperature reached may be 20.0°, and the minimum temperature 12.0°. On 30.0% of the days the mean maximum temperature may be exceeded and on 43.3% of the days the temperature may fall below the mean minimum.

43.3% of the days have rain, the mean for the month being 66.5 mm.

The mean RH is 71.1%, but on 73.3% of the days the RH may fall below the mean. In the top 16.5 cm the soil moisture is 90.1%

In summary, November shows an increase in all temperatures over the October means. With the absence of frosts, rising temperatures, decreasing rainfall and percentage of days with rain, plant growth and flowering increases rapidly, as does the number of organisms in the top soil and in the total population. The deposition of eggs by litter-dwelling animals reaches its maximum as pollen becomes available from the increased flowering of plants, and the total depth of leaf-litter increases.


NOVEMBER

DECEMBER

During December the mean vegetation height is 20.0 cm; clumps may reach 48.0 cm, and litter depth is 4.0 cm.

In December the greatest number of species of plants are in flower, although the main growth period of the vegetation has been completed. Yarrow comes into its maximum flowering, as do red top and brown top. Scarlet pimpernel declines. Sweet vernal declines and finishes flowering at the end of December. Lawn daisies slowly decline, to come to their minimum flowering at the end of December. Prairie grass finishes by the middle of December. Mouse-eared chickweed continues to flower. During the middle of December Scotch thistle comes into flower, reaching its maximum at the end of the month. Hawksbeard and cat's ear continue to increase their flowering. Cocksfoot has reached its maximum, and by the end of December finishes flowering. Yorkshire fog slowly declines. Perennial rye is at its maximum flowering in December. Lotus uliginosa increases flowering rapidly to reach its maximum by the end of December, as does creeping mallow. Pennyroyal starts to flower in the middle of December, increasing slowly towards the end. Paspalum dilatatum and Paspalum paspaloides begin their flowering, although the maximum flowering of dilatatum is reached before that of paspaloides. Narrow-leaved plantain reaches its maximum flowering at the end of December, although broad-leaved plantain has not yet reached this maximum. Poa slowly declines. Selfheal comes into flower at the beginning of december and reaches its maximum at the end. Creeping buttercup and dock reach their maximum at the end of December. Onehunga weed reaches its maximum. The flowering of dandelion slowly increases through December, although there is a decline in flowering in white clover and speedwell.

The total fauna shows a marked increase even over the November increase, reaching an early summer maximum by the middle of December. The numbers of all groups increase with the exception of the Collembola which show a slight drop away in the surface-dwelling forms towards the end of December.

61.0 cm above the surface the mean air temperature is 18.9°, the mean maximum 21.4° and the mean minimum 16.4°. The temperature may reach 28.0° and fall to 3.0°. 64.5% of the days in December the temperaturesmay rise above the mean maximum and on 77.4% of the days they fall below the mean minimum.

At the interface the average temperature is 18.6°, the mean maximum 20.9°, the mean minimum 16.5°. Temperatures may rise to 25.5° or fall to 13.0°. On 29.0% of the days in December the temperature may exceed the mean maximum, and on 41.9% of the days they fall below the mean minimum.

In the top soil, the mean temperature is 19.1°, the mean maximum 20.1°, the mean minimum 17.6°. Maximum temperature may be 23.0°, minimum 15.0°. On 35.5% of the days the mean maximum may be exceeded and on 32.3% of the days the temperature may fall below the mean minimum.

38.7% of the days will have rain, 58.7 mm for December.

The mean RH is 70.9%, but on 80.6% of the days the RH will fall below this mean. Soil moisture in the top 16.5 cm is 87.00%.

In summary, the maximum spring growth is past, but the numbers of the fauna are increasing rapidly. As temperature rises, the number of species of plants in flower increases over the November level. Interface and soil temperatures remain high, but not as high as in January. The percentage of days with rain and the total precipitation is less than in November, but the RH stays close to the November means. The soil moisture, however, decreases considerably from the November figures.


DECEMBER

CONCLUSION

It has been stated in the introduction that this investigation was designed as a long-term study to examine the effects of vegetation retention upon the biota of an enclosed pasture area. The emphasis has not been upon the responses of particular species as such, but on the changes of groups of biota in relation to environmental factors, both annual and over a longer period of time.

Soil and soil profiles are similar at Hillcrest, Newstead and Tamahere, as is the pH of the top soil.

The initial floral content was similar at each site.

Macro-climate at the three sites is similar, although some local variation may occur through short-term, intense precipitation.

The only major difference between the sites is that Hillcrest has remained with a full vegetation cover throughout the period of investigation, while systematic removal of vegetation occurred at the other two sites.

Surface and micro-climate variations can be linked directly with the depth of vegetation and litter present. Where a strong plant cover exists at Hillcrest, soil moisture content at the surface and interface remains higher in summer than at Newstead or Tamahere. Summer maximum temperatures of top soil and interface are lower at Hillcrest than at the other two sites; winter minimum temperatures are higher, and temperature fluctuations are not as wide during the year where a strong plant cover is present.

The numbers of interface and top soil invertebrates show less variation at Hillcrest than at Newstead and Tamahere as a direct consequence of macro-climate modification and buffering by a vegetation cover.

As well as the climatic effect, the maintenance of a vegetation cover will cause suppression of small, low growing plants, and lead to an orderly successional change in plant species.

Finally, the author believes this investigation indicates that the quality of the invertebrate population of a pasture is largely influenced by the depth of litter and height of vegetation within the pasture. Where systematic vegetation removal occurs, the succession of flora is suspended and some faunal groups, e.g., litter and surface dwellers, are prevented from developing their full population potential. This could have important implications for pasture management programmes.

SOME SUGGESTIONS FOR FURTHER RESEARCH

The detailed work of Adams (1971) on New Zealand Collembola, Lee (1959) on New Zealand Lumbricidae, McMillan (1969) on New Zealand Acari and Collembola, and Scott (1966) on New Zealand terrestrial Isopoda must be continued, and extended to include the systematic study of other soil biota, providing information on the relationships between biota in the field. To quote Lee (1968) in his presidential address to the New Zealand Ecological Society, "In New Zealand soils there are many groups, particularly of animals, of which we know virtually nothing, and there is an open field for taxonomic and ecological work", and, "Now that efficient methods of extraction are available, soil animals are a fruitful and readily accessible field for students of animal populations, and for establishing basic principles in the study of mechanisms of competition between species, reaction to environmental change, control of animal populations and many other fundamental aspects of animal ecology."

It is with Lee's words in mind that the author suggests some extensions to research studies.

Above all, exact identification of biota is essential, but this must work hand in hand with the gathering of field data unaffected by laboratory conditions.

1. Long-term studies in other areas of similar soil and floral composition should occur, so that truly valid comparisons can be made with areas differing in soil type, flora and microclimate. Where possible, fauna should be studied in situ with minimal disturbance, so that the feeding and competitive relationships can be determined.

2. Single species study in the laboratory will add depth to data collected in the field, particularly with respect to New Zealand Acarina, Collembola and Enchytraeidae.

3. The effects of exo-metabolites need precise definition to determine the effect upon the behaviour of fauna and its vertical, seasonal and long-term distribution patterns.

   Only when this basic research has been accomplished can the effects of environmental manipulation through agricultural practice be seen in their full ecological perspective.

4. The author's findings can be extended into the field of applied agriculture -

   (a) What are the effects upon specific faunal groups of fertiliser application of varied quantities?

   (b) Could the application of a natural or artificial mulch to prepared pastures aid the rate of organic turnover during the critical period of summer as soil temperatures rise and soil moisture falls?

   (c) Does pasture monoculture deplete the topsoil of some faunal groups, leading to an increase in numbers of some "pest" invertebrates, or is the increase a long-term cyclic process?

ACKNOWLEDGEMENTS

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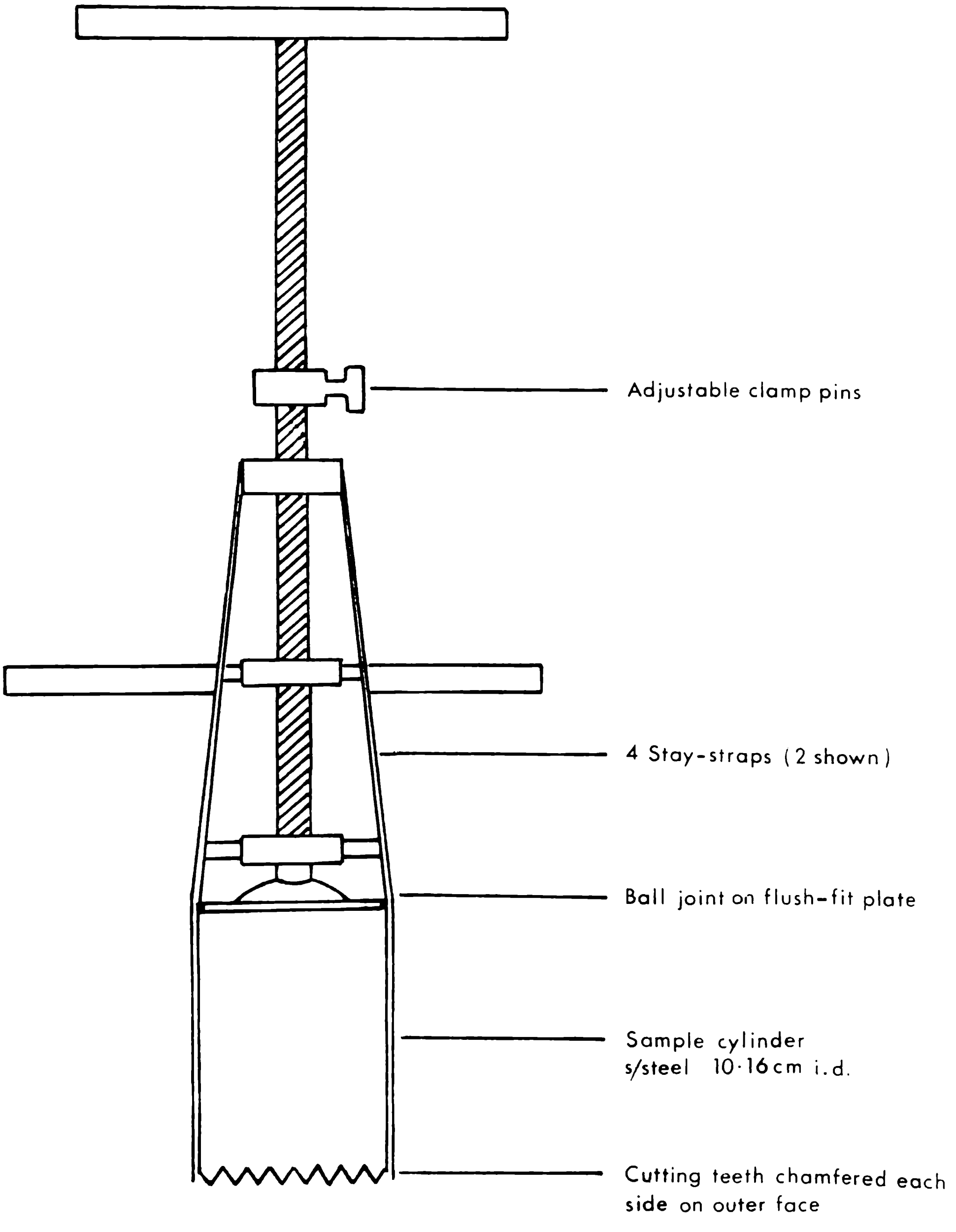
A special acknowledgement must go to my wife who helped at every stage, encouraging during the "down" times, and quietly rejoicing when things were going well. Her strength of character and patience enabled the research to be completed.

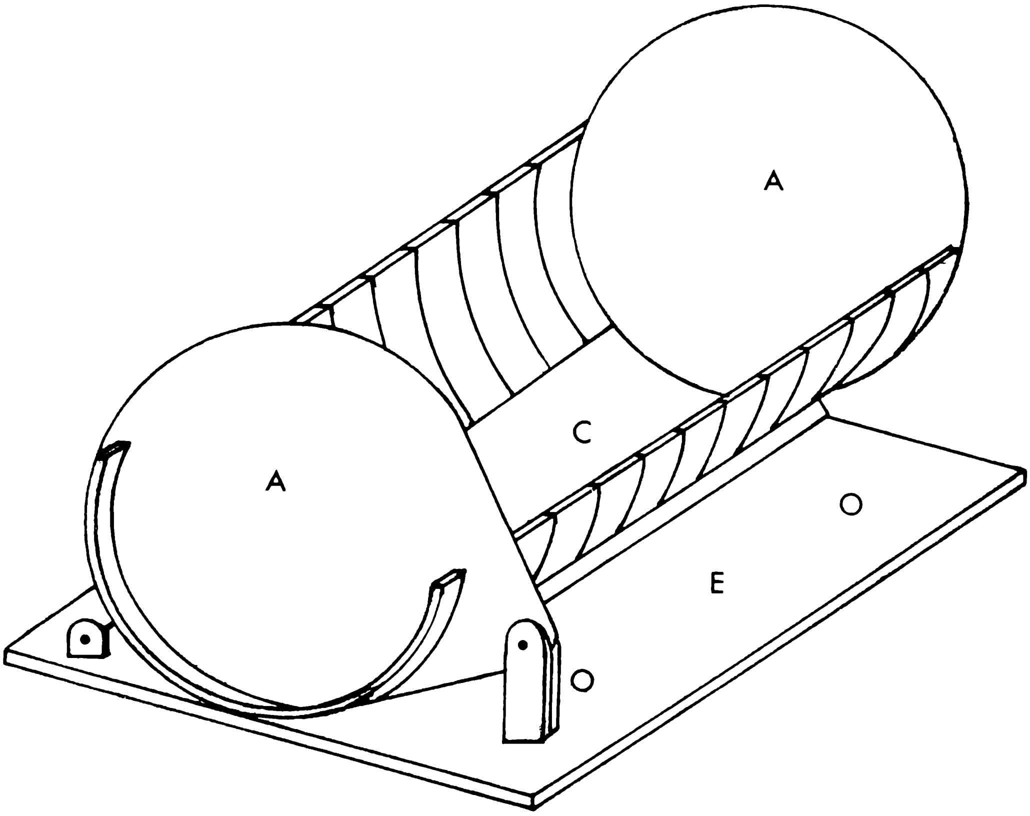
FIGURE 1

SOIL SAMPLER

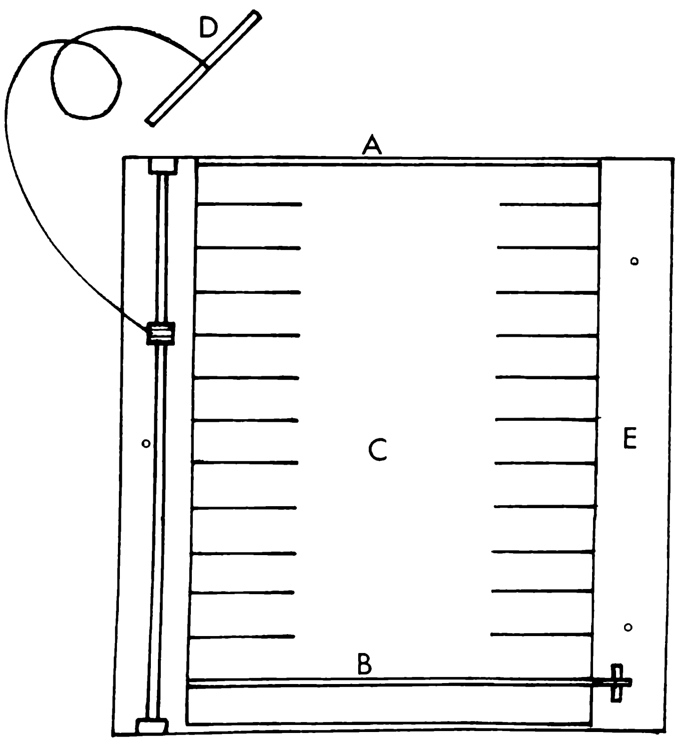


Scale $\frac{1}{5}$

FIGURE 2 SOIL SECTIONER



STRUCTURAL DETAIL



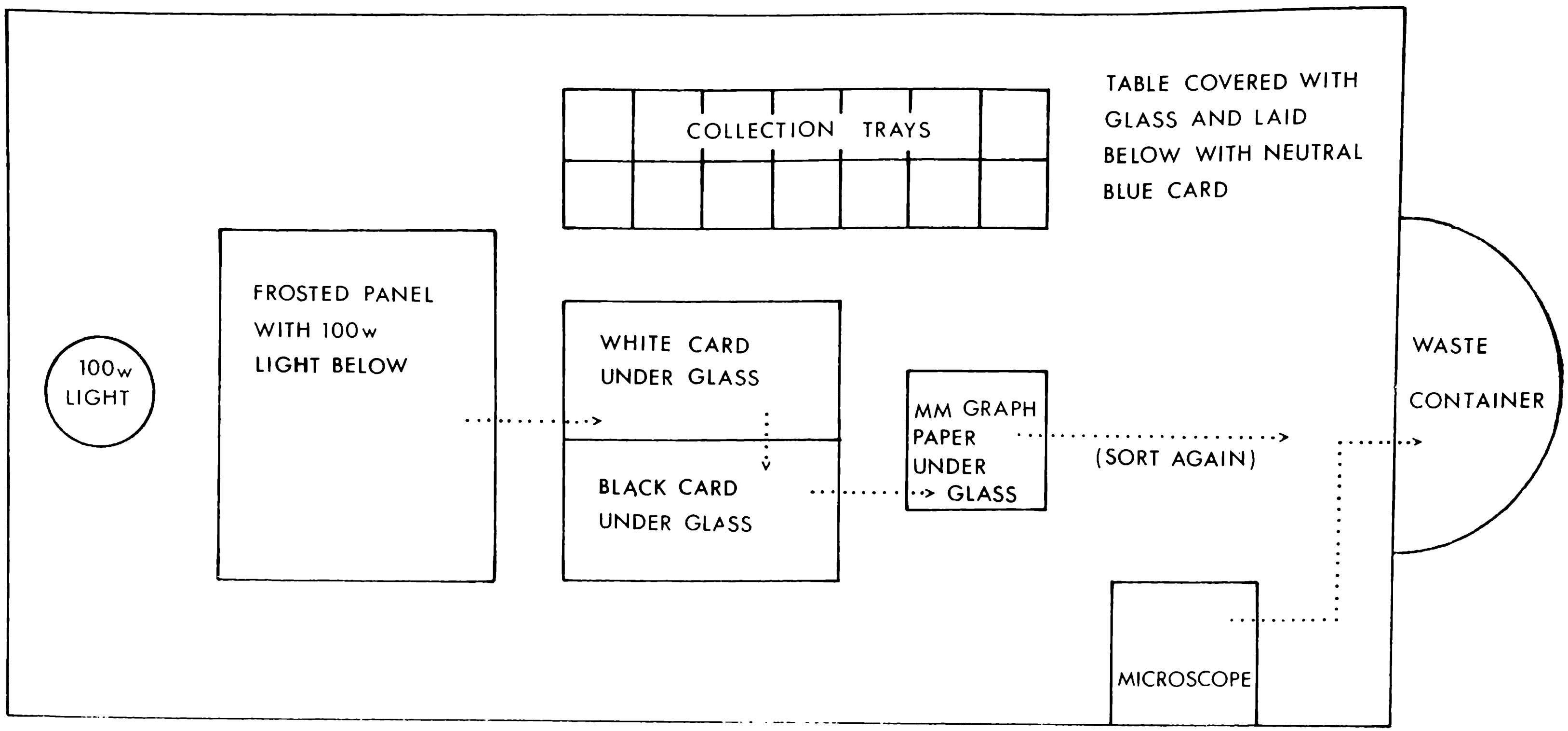
KEY

- A Fixed top plate
- B Moveable bottom plate
- C Core receptacle slotted at 1cm intervals
- D Piano wire with handle and sliding ring
- E Base plate

Scale $\frac{1}{2}$

SECTION DETAIL

FIGURE 3 METHOD OF HAND-SORTING



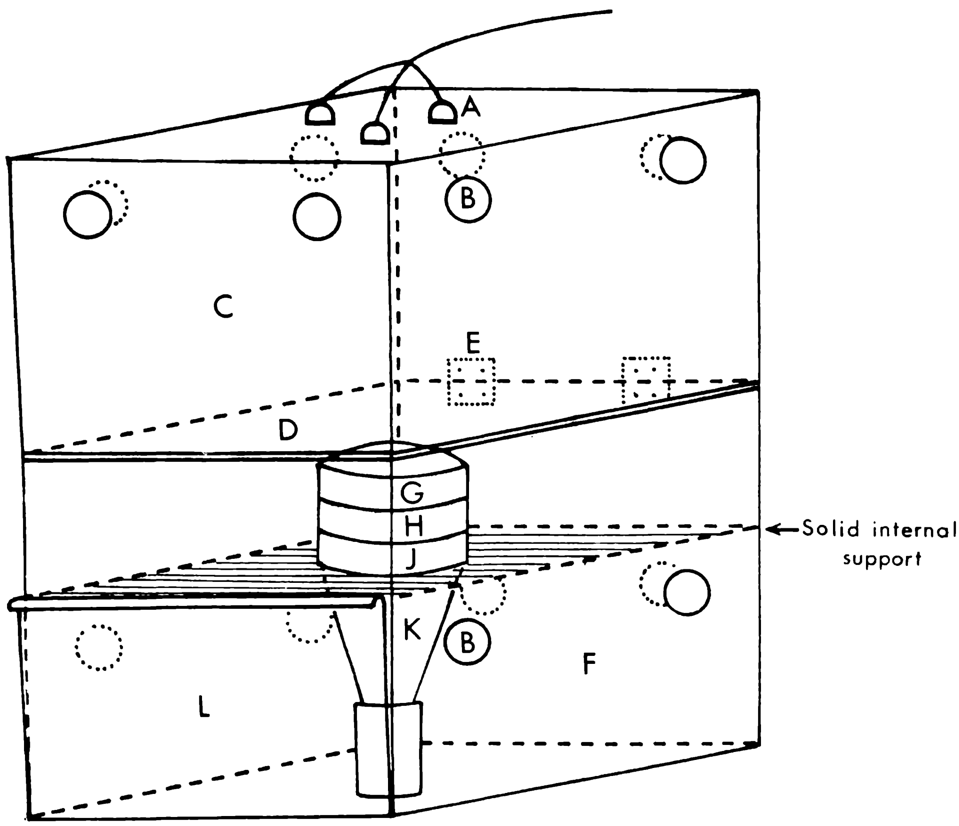
·····> Direction of soil sorting

Scale $\frac{1}{6}$

X OPERATOR

FIGURE 4

SPLIT FUNNEL EXTRACTOR



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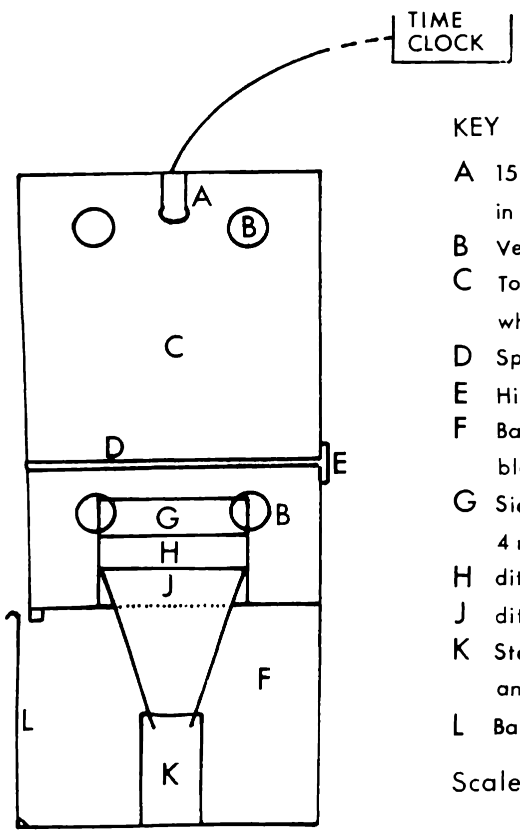


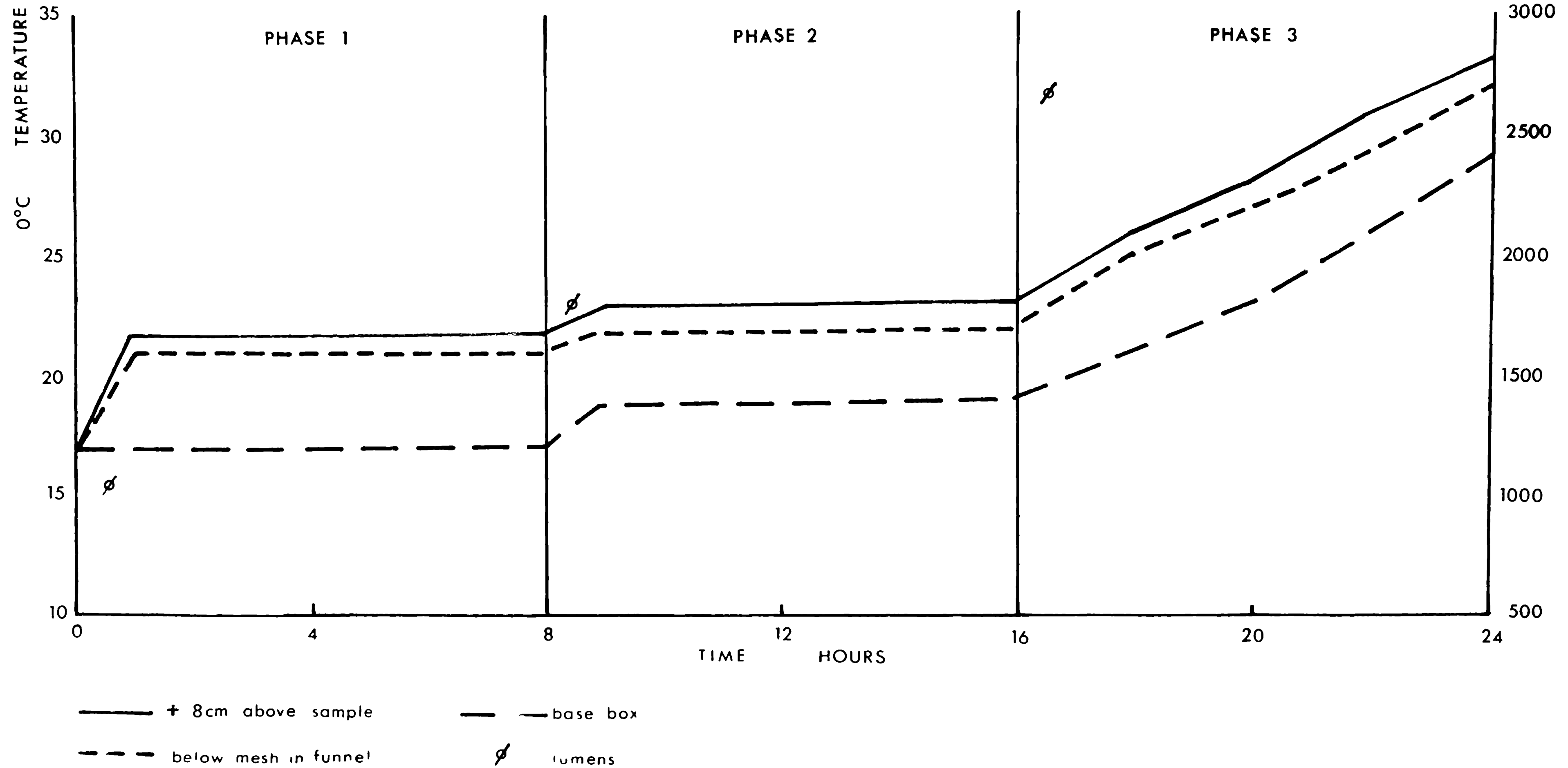
KEY

A 15w clear lights three in parallel circuits
B Ventilation holes
C Top box reflective white inside
D Sponge plastic buffer
E Hinge
F Base box matte black inside
G Sieve in ring support 4 mesh/cm^2
H ditto 16 mesh/cm^2
J ditto 32 mesh/cm^2
K Steep angle funnel and collecting vial
L Base hinged door

Scale $\frac{1}{5}$

SECTION DETAIL

GRAPH 8 TEMPERATURE AND ILLUMINATION IN EXTRACTOR

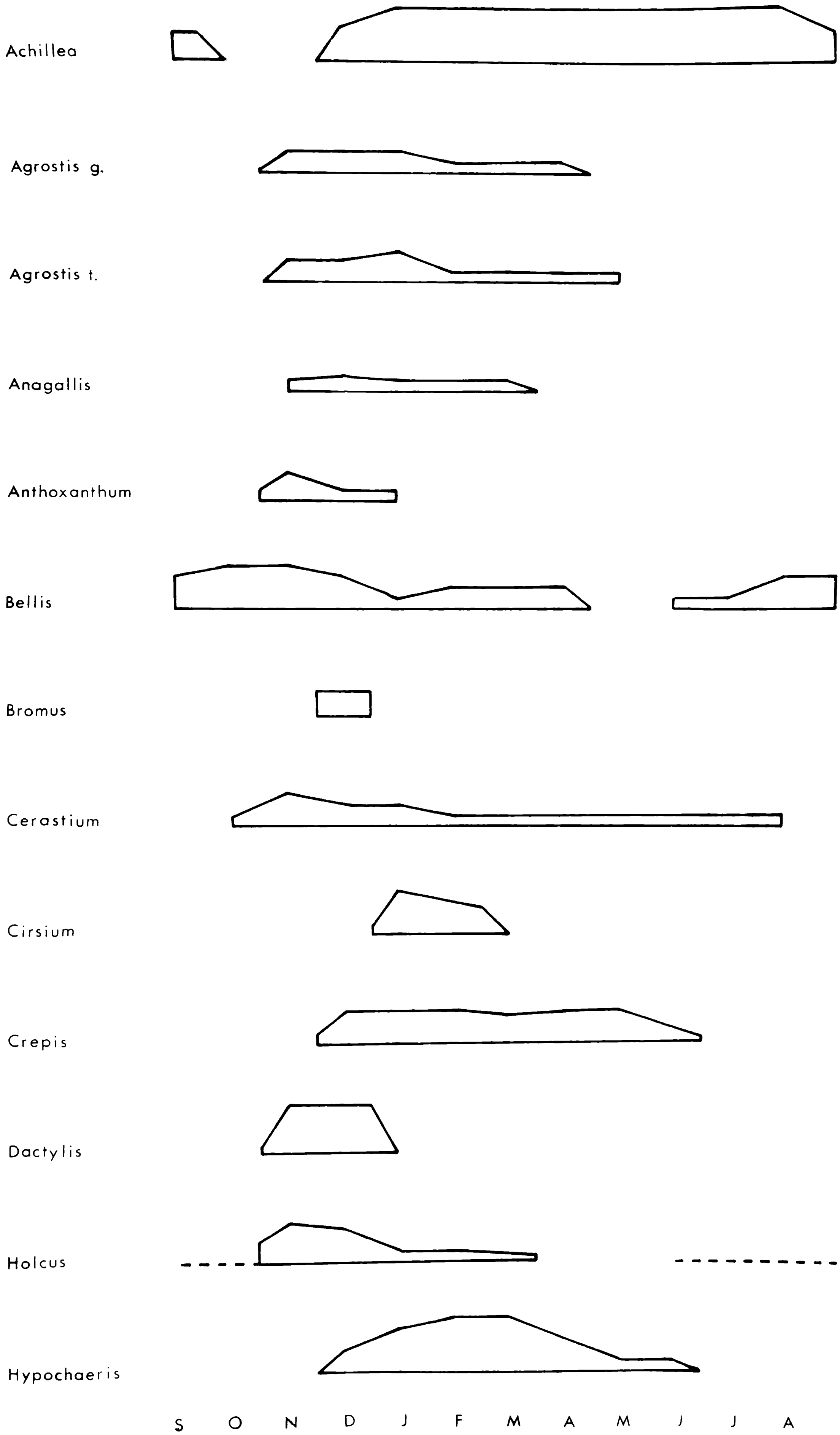


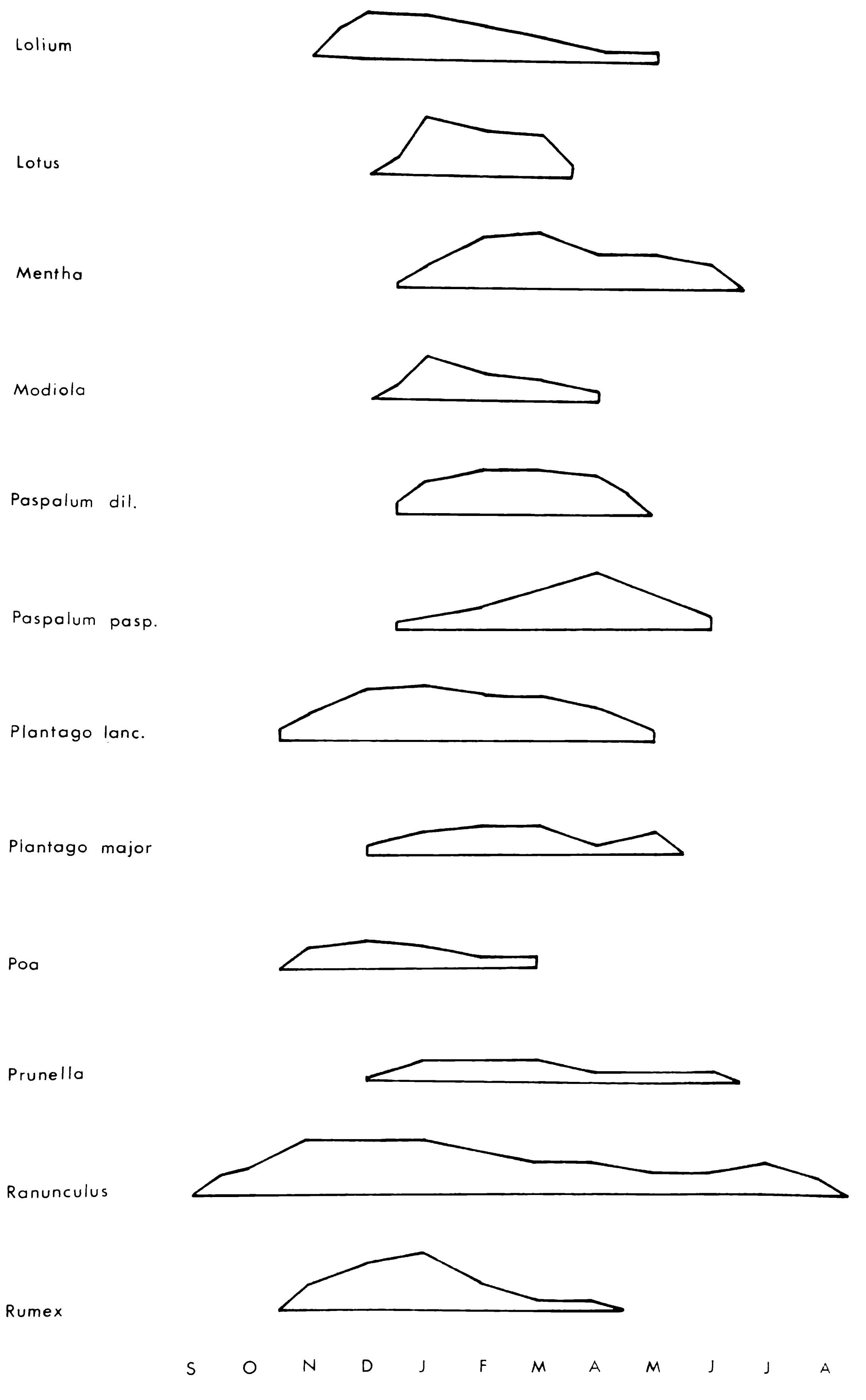
APPENDIX No. 1

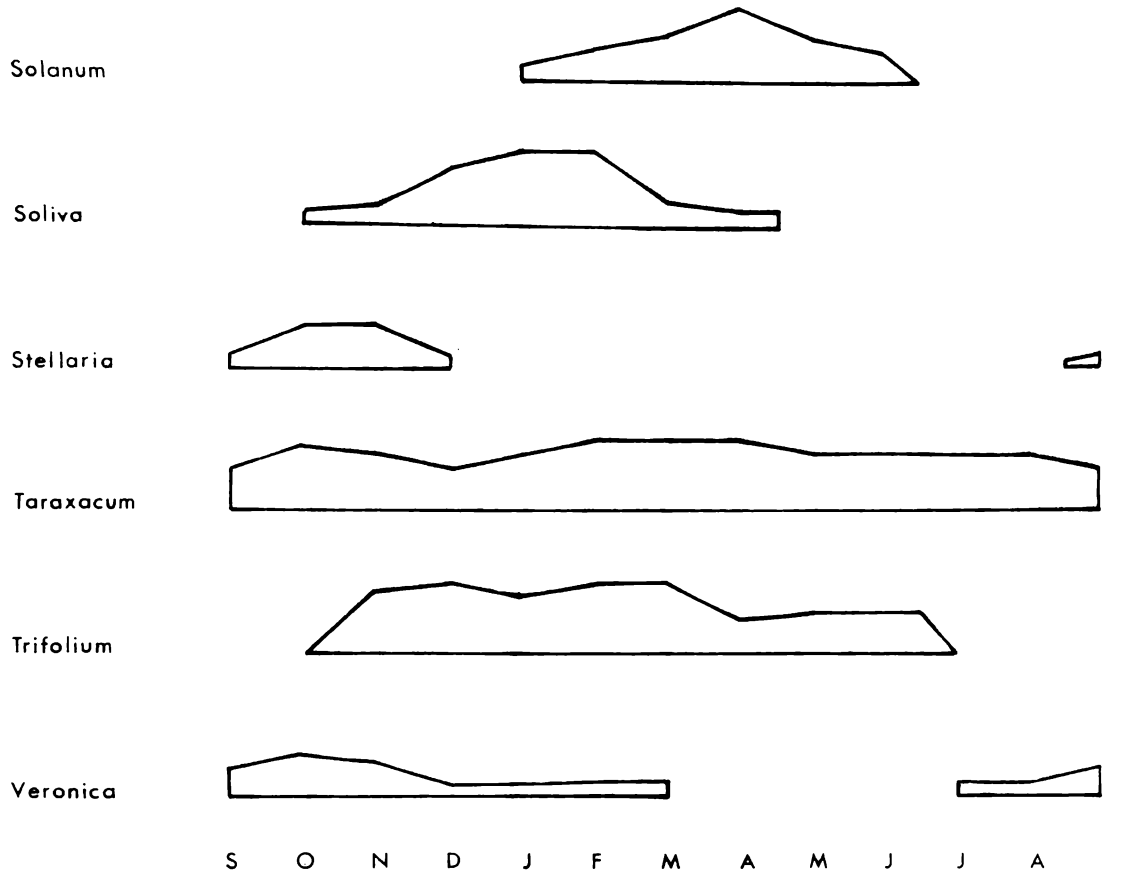
PHENOLOGY OF FLOWERING - HILLCREST

MEAN TIMES 1967 - 1971

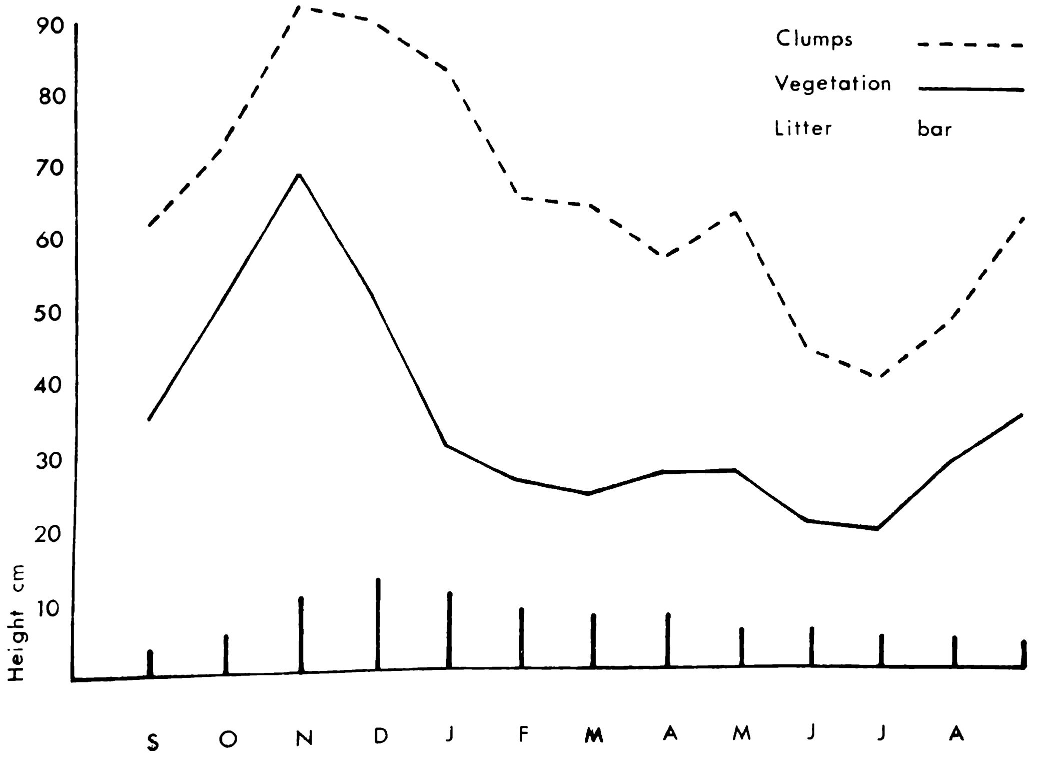
Vertical scale (2 mm = 1 year) indicates the number of years when the species flowered.


Achillea
Agrostis g.
Agrostis t.
Anagallis
Anthoxanthum
Bellis
Bromus
Cerastium
Cirsium
Crepis
Dactylis
Holcus
Hypochaeris
S O N D J F M A M J J A


Lolium
Lotus
Mentha
Modiola
Paspalum dil.
Paspalum pasp.
Plantago lanc.
Plantago major
Poa
Prunella
Ranunculus
Rumex
S O N D J F M A M J J A



MEAN HEIGHTS - CLUMPS, VEGETATION, LITTER - HILLCREST, 1967-1971



APPENDIX No.2

BLE'S SOLUTION

glycerol	49 cc
95% methanol	49 cc
40% formaldehyde	2 cc

....

FAURE'S MEDIUM

1.	distilled water	50 cc
2.	chloral hydrate	50 gm
3.	glycerol	20 ml
4.	gum arabic	30 gm

Mix in order 1 through 4; stir and filter; ready for use in 12 hours.

....

OUDEMAN'S FLUID

70% methanol	87 cc
glycerol	5 cc
glacial acetic acid	8 cc

(This fluid has the advantage that it leaves the appendages of micro-arthropods extended.)

....

EXTRACTION SOLUTION

aqueous picric acid	75 cc
70% methanol	20 cc
glycerol	5 cc

....

APPENDIX No.3

SOIL NITRATE DETERMINATION - QUICK METHOD

1. Shake 50 gm of dry pulverised soil with 250 ml distilled water containing 5 ml of N $CuSO_4 \cdot 5H_2O$ for 10 minutes.

2. Add 0.4 gm of $Ca(OH)_2$ and 1 gm of $MgCO_3$. Shake for 5 minutes to precipitate Cu and Fe. Filter but discard the first 20 ml of the filtrate.

3. To 1 ml of the sample solution in a dry test tube add 1 ml of dilute phenoldisulphonic acid. Shake gently and leave for 2 minutes.

4. Add 23 ml of diluting solution and compare resulting solution with the standard Lovibond comparator disc.

....

(Diluting solution :

Ammonium citrate	5 gm
880 Ammonia solution	125 ml

add distilled water to bring to 1 litre.)

....

APPENDIX No.4

LAYOUT OF DATA CARDS STORED AT UNIVERSITY OF WAIKATO

CARD 1.

Cols	1 - 3	RBG
"	4 - 5	Year
"	6	Card No.
"	7 - 10	Date
"	11 - 13	Staphylinidae
"	14 - 16	Mesostigmatids
"	17 - 19	Collembola
"	20 - 22	Lumbricidae
"	23 - 25	L. Egg Case
"	26 - 28	Araneida
"	29 - 31	Carabidae
"	32 - 34	C. Larvae
"	35 - 37	C. Eggs
"	38 - 40	Scarab larvae
"	41 - 43	S. Adult
"	44 - 46	Stratiomyid larvae
"	47 - 49	S. Pupae
"	50 - 52	Formicidae
"	53 - 55	Mollusca
"	56 - 58	M. Eggs
"	59 - 61	Chalcidae
"	62 - 64	Chilopoda
"	65 - 67	Enchytraeidae
"	68 - 70	Elateridae larvae
"	71 - 73	pH

CARD 2

Cols	1 - 3	RBG
"	4 - 5	Year
"	6	Card No.
"	7 - 10	Date
"	11	Bromus unioloides
"	12	Lotus uliginosa
"	13	Trifolium repens
"	14	Lolium perenne
"	15	Achillea millefolium
"	16	Plantago lanceolata
"	17	Plantago major
"	18	Taraxacum officinale
"	19	Mentha pulegium
"	20	Paspalum dilatatum
"	21	Paspalum paspaloides
"	22	Poa annua
"	23	Ranunculus sardous
"	24	Rumex obtusifolius
"	25	Agrostis gigantea
"	26	Solanum nigrum
"	27	Holcus lanatus
"	28	Hypochaeris radicata
"	29	Dactylis glomerata
"	30	Cerastium glomeratum
"	31	Agrostis tenuis
"	32 - 34	Depth Litter
"	35 - 37	Height Vegetation
"	38 - 40	MN RH - Air

CARD 2 (continued)

Cols	41 - 43	MN - Air
"	44 - 46	ABS MX - Air
"	47 - 49	ABS MIN - Air
"	50 - 52	MN MAX - Air
"	53 - 55	MN MIN - Air
"	56 - 58	MN Soil
"	59 - 61	MX Soil - ABS
"	62 - 64	MN Soil - ABS
"	65 - 67	MN Surface
"	68 - 70	MX Surface - ABS
"	71 - 73	MN Surface - ABS
"	74 - 76	Total Rain (7 days before sampling)

KEY TO APPENDIX 4

Row	1	Mesostigmatidae
	2	Collembola
	3	Lumbricidae
	4	Scarabid larvae
	5	Stratiomyid larvae
	6	Mollusca
	7	Enchytraeidae
	8	pH
	9	Bromus unioloides
	10	Trifolium repens
	11	Lolium perenne
	12	Achillea millefolium
	13	Plantago major
	14	Mentha pulegium
	15	Paspalum paspaloides
	16	Ranunculus sardous
	17	Holcus lanatus
	18	Dactylis lanatus
	19	Agrostis tenuis
	20	Depth of litter
	21	Height of vegetation
	22	Mean R.H.
	23	Mean air temperature
	24	Mean maximum air temperature
	25	Mean minimum air temperature
	26	Mean soil temperature
	27	Maximum soil temperature

Row	28	Minimum soil temperature
	29	Mean surface temperature
	30	Maximum surface temperature
	31	Minimum surface temperature
	32	Rainfall
	33	Time

```
ROW 1
  1.000  0.464 -0.222 -0.560  0.568  0.575  0.490  0.561  0.096 -0.404 -0.535 -0.558 -0.519  0.309 -0.027 -0.414  0.004
 -0.289  0.465  0.285 -0.471 -0.637 -0.612 -0.592 -0.592 -0.591 -0.597 -0.600 -0.584 -0.602 -0.612 -0.424 -0.407

ROW 2
  0.464  1.000 -0.274 -0.369  0.753  0.683  0.330  0.588 -0.235 -0.377 -0.708 -0.203 -0.693  0.312  0.372 -0.584  0.263
 -0.301  0.521  0.102 -0.698 -0.761 -0.779 -0.772 -0.775 -0.768 -0.770 -0.773 -0.771 -0.766 -0.769 -0.724 -0.396

ROW 3
 -0.222 -0.274  1.000  0.263 -0.211 -0.217 -0.164 -0.249 -0.155  0.228  0.115  0.217  0.277 -0.034  0.012  0.427 -0.014
  0.891 -0.061 -0.103 -0.110  0.175  0.196  0.203  0.221  0.176  0.205  0.207  0.228  0.189  0.198  0.184 -0.164

ROW 4
 -0.560 -0.369  0.263  1.000 -0.290 -0.455 -0.471 -0.519 -0.131  0.568  0.156  0.442  0.300 -0.399  0.246  0.231  0.004
  0.303 -0.330 -0.513  0.146  0.333  0.351  0.324  0.334  [illegible]  [illegible]  [illegible]  [illegible]  0.329  [illegible]  0.241  [illegible]

ROW 5
  0.568  0.753 -0.211 -0.290  1.000  0.826  0.320  0.585 -0.315 -0.096 -0.883 -0.065 -0.840  0.207  0.629 -0.714  0.077
 -0.414  0.515 -0.381 -0.360 -0.976 -0.938 -0.983 -0.985 -0.979 -0.984 -0.984 -0.982 -0.978 -0.978 -0.968 -0.479

ROW 6
  0.575  0.683 -0.217 -0.455  0.826  1.000  0.757  0.873 -0.202 -0.211 -0.782 -0.186 -0.746  0.440  0.228 -0.635  0.200
 -0.395  0.635  0.423 -0.739 -0.866 -0.881 -0.873 -0.876 -0.869 -0.875 -0.877 -0.871 -0.873 -0.877 -0.800 -0.460

ROW 7
  0.458  0.330 -0.164 -0.471  0.320  0.757  1.000  0.865 -0.092 -0.314 -0.365 -0.401 -0.420  0.528 -0.372 -0.342  0.311
 -0.190  0.175  0.874 -0.354 -0.403 -0.423 -0.414 -0.417 -0.411 -0.417 -0.417 -0.412 -0.415 -0.418 -0.353 -0.225

ROW 8
  0.561  0.588 -0.249 -0.519  0.585  0.873  0.865  1.000 -0.180 -0.459 -0.602 -0.511 -0.656  0.436 -0.106 -0.484  0.261

 -0.292  0.366  0.777 -0.567 -0.647 -0.667 -0.661 -0.665 -0.657 -0.664 -0.663 -0.660 -0.662 -0.662 -0.573 -0.339

ROW 9
  0.096 -0.235 -0.155 -0.131 -0.315 -0.202 -0.092 -0.180  1.000  0.016  0.427  0.123  0.377 -0.065 -0.195  0.596 -0.042
 -0.045  0.087  0.024  0.527  0.227  0.311  0.346  0.345  0.350  0.344  0.330  0.349  0.319  0.205  0.440 -0.050

ROW 10
 -0.404 -0.377  0.228  0.568 -0.096 -0.211 -0.314 -0.459  0.016  1.000  0.146  0.520  0.228 -0.279  0.291  0.105 -0.121
  0.099 -0.201 -0.454  0.155  0.168  0.177  0.175  0.179  0.172  0.175  0.175  0.181  0.175  0.176  0.154  0.087

ROW 11
 -0.535 -0.709  0.115  0.156 -0.383 -0.782 -0.365 -0.602  0.427  0.146  1.000  0.112  0.681 -0.265 -0.505  0.670 -0.120
  0.324 -0.440 -0.018  0.908  0.907  0.890  0.925  0.916  0.936  0.919  0.922  0.915  0.920  0.921  0.904  0.640
```

ROW 12
-0.558 -0.233 0.217 0.442 -0.068 -0.186 -0.421 -0.511 0.123 0.520 0.112 1.000 0.295 -0.144 0.302 0.257 -0.115
0.123 0.033 -0.519 0.101 0.091 0.111 0.104 0.105 0.098 0.107 0.104 0.102 0.099 0.095 -0.014 0.005

ROW 13
-0.519 -0.693 0.277 0.300 -0.840 -0.746 -0.420 -0.656 0.377 0.228 0.661 0.295 1.000 -0.155 -0.404 0.735 -0.111
0.377 -0.393 -0.109 0.782 0.815 0.857 0.824 0.832 0.810 0.822 0.821 0.819 0.794 0.791 0.644 0.415

ROW 14
0.305 0.312 -0.034 -0.399 0.207 0.440 0.528 0.436 -0.086 -0.279 -0.265 -0.144 -0.155 1.000 -0.159 -0.274 0.213
-0.086 0.394 0.422 -0.230 -0.231 -0.254 -0.249 -0.250 -0.249 -0.253 -0.251 -0.245 -0.244 -0.246 -0.226 -0.126

ROW 15
-0.017 0.372 0.012 0.246 0.629 0.228 -0.372 -0.106 -0.155 0.291 -0.505 0.381 -0.404 -0.169 1.000 -0.380 -0.195
-0.214 0.334 -0.663 -0.489 -0.542 -0.542 -0.545 -0.546 -0.547 -0.544 -0.546 -0.548 -0.541 -0.541 -0.556 -0.263

ROW 16
-0.414 -0.584 0.427 0.231 -0.714 -0.635 -0.342 -0.484 0.556 0.105 0.670 0.257 0.736 -0.274 -0.350 1.000 -0.117
0.556 -0.233 -0.048 0.651 0.645 0.711 0.700 0.709 0.685 0.699 0.697 0.700 0.562 0.635 0.022 0.233

ROW 17
0.064 0.263 -0.014 0.004 0.077 0.260 0.311 0.281 -0.045 -0.121 -0.120 -0.123 -0.111 0.210 -0.195 -0.117 1.000
-0.045 0.097 0.255 -0.110 -0.095 -0.123 -0.121 -0.121 -0.119 -0.124 -0.121 -0.119 -0.122 -0.119 -0.087 -0.054

ROW 18
-0.289 -0.301 0.091 0.303 -0.414 -0.395 -0.190 -0.292 -0.045 0.099 0.324 0.123 0.377 -0.086 -0.214 0.556 -0.045
1.000 -0.200 -0.028 0.078 0.371 0.392 0.414 0.429 0.389 0.416 0.416 0.439 0.398 0.406 0.375 -0.054

ROW 19
0.465 0.521 -0.061 -0.330 0.516 0.525 0.175 0.366 0.097 -0.201 -0.448 0.033 -0.393 0.094 0.334 -0.030 0.087
-0.200 1.000 0.050 -0.410 -0.549 -0.549 -0.526 -0.530 -0.524 -0.530 -0.533 -0.521 -0.533 -0.542 -0.467 -0.344

ROW 20
0.285 0.102 -0.103 -0.513 -0.081 0.423 0.874 0.707 0.024 -0.454 -0.018 -0.519 -0.109 0.422 -0.033 -0.046 0.255
-0.028 0.050 1.000 -0.019 -0.017 -0.034 -0.028 -0.032 -0.027 -0.031 -0.031 -0.029 -0.032 -0.034 [illegible] -0.034

ROW 21

-0.471 -0.698 -0.110 0.146 -0.860 -0.739 -0.354 -0.567 0.527 0.155 0.908 0.101 0.752 -0.220 -0.489 0.881 -0.110
0.078 -0.410 -0.019 1.000 0.864 0.879 0.866 0.876 0.897 0.876 0.880 0.868 0.869 0.857 0.809 0.594

ROW 22
-0.637 -0.761 0.175 0.333 -0.976 -0.566 -0.403 -0.647 0.227 0.168 0.907 0.091 0.815 -0.231 -0.542 0.643 -0.095
0.371 -0.549 -0.017 0.884 1.000 0.957 0.986 0.984 0.986 0.984 0.987 0.979 0.984 0.989 0.894 0.602

```
ROW 23
-0.512 -0.779  0.196  0.351 -0.988 -0.881 -0.423 -0.367  0.311  0.177  0.59[illegible]  0.111  0.857 -0.254 -0.842  0.711 -0.123
 0.392 -0.549 -0.034  0.879  0.987  1.000  0.993  0.994  0.989  0.993  0.993  0.990  0.966  0.968  0.906  0.904

ROW 24
-0.592 -0.772  0.203  0.324 -0.983 -0.873 -0.414 -0.361  0.346  0.175  0.925  0.104  0.824 -0.249 -0.548  0.700 -0.121
 0.414 -0.526 -0.028  0.883  0.985  0.993  1.000  0.995  0.999  0.999  0.99[illegible]  0.998  0.997  0.996  0.939  0.507

ROW 25
-0.592 -0.775  0.221  0.334 -0.995 -0.876 -0.417 -0.665  0.343  0.179  0.916  0.105  0.832 -0.250 -0.546  0.709 -0.121
 0.429 -0.530 -0.032  0.878  0.984  0.994  0.995  1.000  0.997  0.99[illegible]  0.99[illegible]  0.999  0.996  0.995  0.936  0.493

ROW 26
-0.591 -0.768  0.176  0.310 -0.979 -0.869 -0.411 -0.657  0.350  0.172  0.936  0.098  0.810 -0.249 -0.547  0.685 -0.119
 0.389 -0.524 -0.027  0.897  0.984  0.989  0.999  0.997  1.000  0.998  0.998  0.996  0.997  0.996  0.943  0.52[illegible]

ROW 27
-0.597 -0.770  0.206  0.330 -0.984 -0.875 -0.417 -0.664  0.344  0.175  0.919  0.107  0.822 -0.253 -0.544  0.699 -0.124
 0.416 -0.530 -0.031  0.878  0.984  0.993  0.999  0.999  0.998  1.000  0.999  0.999  0.998  0.998  0.940  0.49[illegible]

ROW 28
-0.600 -0.773  0.217  0.331 -0.984 -0.877 -0.417 -0.663  0.330  0.175  0.922  0.104  0.821 -0.251 -0.546  0.697 -0.121
 0.413 -0.533 -0.031  0.880  0.987  0.993  0.999  0.999  0.998  0.999  1.000  0.998  0.997  0.997  0.937  0.507

ROW 29
-0.534 -0.771  0.228  0.323 -0.982 -0.871 -0.412 -0.660  0.349  0.181  0.915  0.102  0.819 -0.245 -0.548  0.700 -0.119
 0.439 -0.521 -0.029  0.868  0.979  0.990  0.998  0.999  0.996  0.999  0.998  1.000  0.997  0.995  0.946  0.468

ROW 30
-0.602 -0.765  0.189  0.329 -0.978 -0.873 -0.415 -0.662  0.319  0.175  0.920  0.099  0.794 -0.244 -0.541  0.802 -0.122
 0.398 -0.523 -0.032  0.869  0.984  0.988  0.997  0.996  0.997  0.998  0.997  0.997  1.000  0.998  0.946  0.49[illegible]

ROW 31
-0.612 -0.769  0.198  0.334 -0.978 -0.877 -0.416 -0.662  0.285  0.176  0.921  0.093  0.781 -0.248 -0.542  0.685 -0.119
 0.416 -0.542 -0.034  0.867  0.959  0.988  0.993  0.995  0.996  0.996  0.997  0.995  0.998  1.000  0.941  0.518

ROW 32
-0.424 -0.724  0.164  0.241 -0.908 -0.800 -0.353 -0.576  0.440  0.134  0.904 -0.014  0.644 -0.226 -0.568  0.622 -0.067
 0.375 -0.467  0.025  0.809  0.894  0.926  0.938  0.930  0.943  0.940  0.937  0.946  0.948  0.941  1.000  0.50[illegible]

ROW 33
-0.407 -0.398 -0.164  0.029 -0.479 -0.460 -0.225 -0.339 -0.050  0.087  0.640  0.005  0.416 -0.128 -0.263  0.233 -0.054
-0.054 -0.344 -0.034  0.694  0.602  0.504  0.507  0.493  0.529  0.490  0.507  0.468  0.490  0.518  0.500  1.000
```

APPENDIX 5

METEOROLOGICAL DATA - HILLCREST - MEANS FOR 1968-71

	Air T° + 61.0 cms.								Interface							Soil - 16.5 cms.											
	Mn	Mn Mx	Mx T°	Mn Min	Min T°	% of days exceeding Mn Mx	% of days exceeding Mn Min	% days of frost	Mn	Mn Mx	Mx T°	Mn Min	Mn T°	% of days exceeding Mn Mx	% of days exceeding Mn Min	Mn	Mn Mx	Mx T°	Mn Min	Mn T°	% of days exceeding Mn Mx	% of days exceeding Mn Min	Precipitation mms.	% of days with rain	Mn RH %	% of days below Mn RH	Mn soil moisture top 16.5 cms.
J	20.3	23.6	31.5	17.0	6.0	61.3	87.1	.	19.9	22.4	26.0	17.2	11.0	45.2	19.4	20.2	21.2	24.0	18.7	16.0	41.9	35.5	39.4	22.6	70.6	100.0	73.40
F	20.6	23.6	30.0	16.5	6.0	85.7	82.1	.	19.0	20.7	25.0	18.0	12.0	71.4	50.0	19.5	21.6	23.0	16.1	16.0	17.9	3.6	34.4	21.4	76.0	92.9	72.00
M	22.0	25.1	31.0	18.9	8.0	77.4	87.1	.	20.2	22.9	25.0	17.4	11.0	61.2	38.7	20.6	21.7	23.0	19.1	16.0	64.5	22.6	31.3	35.5	76.1	80.6	86.00
A	15.6	17.5	25.0	13.6	3.0	66.7	66.7	.	15.3	17.4	22.0	15.4	8.0	36.7	93.3	16.5	16.9	21.5	15.5	12.0	46.7	43.3	200.3	66.7	81.8	76.7	94.10
M	12.7	15.2	21.0	10.2	0.0	77.4	67.7	3.2	12.0	14.4	19.0	9.3	3.0	41.9	32.3	13.3	14.0	18.0	12.0	8.0	32.3	38.7	186.0	64.5	86.7	64.5	97.10
Jn	10.5	12.4	13.0	8.6	-3.0	71.0	58.1	3.7	10.0	12.7	13.0	7.6	-1.0	67.7	35.5	11.2	11.8	14.0	10.3	5.0	64.5	29.0	161.0	71.0	87.1	74.2	100.00

METEOROLOGICAL DATA - HILLCREST - MEANS FOR 1968-71 (continued)

	Mn per Month	D	N	O	S	A	J
Air T° + 61.0 cms. Mn	15.0	18.9	16.2	13.2	11.2	10.7	9.0
Air T° + 61.0 cms. Mn Mx	17.6	21.4	18.9	15.2	13.5	12.9	11.6
Air T° + 61.0 cms. Mx T°	24.1	28.0	29.0	22.0	19.0	18.0	17.0
Air T° + 61.0 cms. Mn Min	12.5	16.4	13.4	11.2	8.7	8.5	6.5
Air T° + 61.0 cms. Min T°	1.7	3.0	3.0	1.0	-1.0	-3.0	-3.0
Air T° + 61.0 cms. % of days exceeding Mn Mx	68.3	64.5	50.0	71.0	76.7	64.5	53.3
Air T° + 61.0 cms. % of days exceeding Mn Min	74.0	77.4	86.7	54.3	76.7	77.4	66.7
% days of frost	5.5	.	.	.	9.9	16.1	26.7
Interface Mn	14.4	18.6	15.9	12.8	11.0	10.4	8.0
Interface Mn Mx	16.9	20.9	18.4	14.7	13.9	13.4	11.7
Interface Mx T°	21.0	25.5	23.0	18.0	17.0	16.0	17.0
Interface Mn Min	12.2	16.3	13.6	11.1	8.5	7.5	4.4
Interface Min T°	6.4	13.0	11.0	7.0	4.0	1.0	-3.0
Interface % of days exceeding Mn Mx	52.4	29.0	43.3	71.0	63.3	41.9	46.7
Interface % of days exceeding Mn Min	45.2	41.9	43.3	32.3	50.0	38.7	66.7
Soil - 16.5 cms. Mn	15.1	19.1	16.0	13.4	11.6	10.9	9.2
Soil - 16.5 cms. Mn Mx	16.0	20.1	16.9	14.1	12.5	11.9	10.3
Soil - 16.5 cms. Mx T°	18.7	23.0	20.0	16.0	15.0	13.0	14.0
Soil - 16.5 cms. Mn Min	13.6	17.6	14.6	12.3	10.3	9.5	7.7
Soil - 16.5 cms. Min T°	10.7	15.0	12.0	10.0	8.0	6.0	4.0
Soil - 16.5 cms. % of days exceeding Mn Mx	45.0	35.5	30.0	48.4	50.0	71.0	36.7
Soil - 16.5 cms. % of days exceeding Mn Min	32.4	32.3	43.3	32.3	30.0	38.7	40.0
Precipitation mms.	104.3	58.7	66.5	96.8	97.6	123.4	156.5
% of days with rain	48.6	38.7	43.3	51.6	60.0	58.1	50.0
Mn RH %	78.0	70.9	71.1	75.3	78.2	81.5	81.2
% of days below Mn RH	80.4	80.6	73.3	83.9	76.7	74.2	86.7
Mn soil moisture top 16.5 cms.	90.39	87.00	90.10	92.00	98.50	98.50	100.00

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NOTE:

The abbreviated titles of journals are in accord with the suggestions of -

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