A STUDY OF
PASTURE PATTERN IN RELATION TO MICROTOPOGRAPHY

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requirements for the degree of

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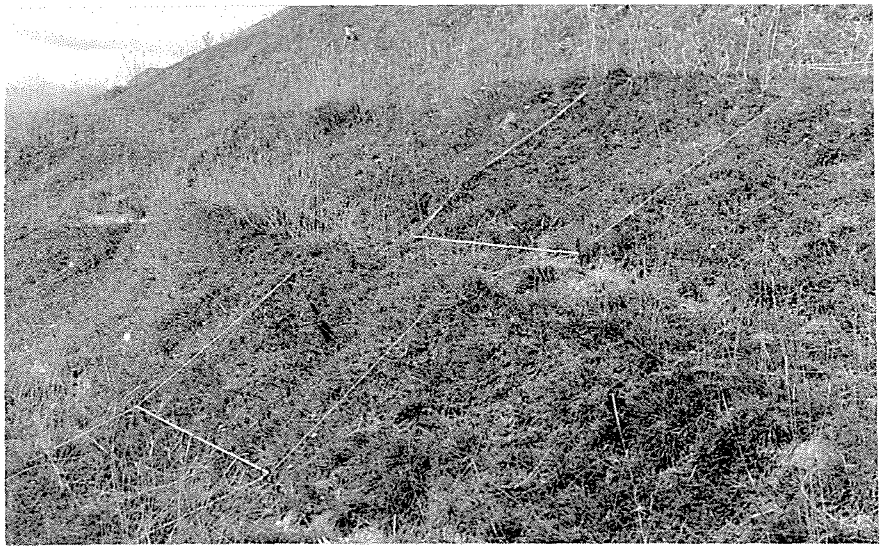

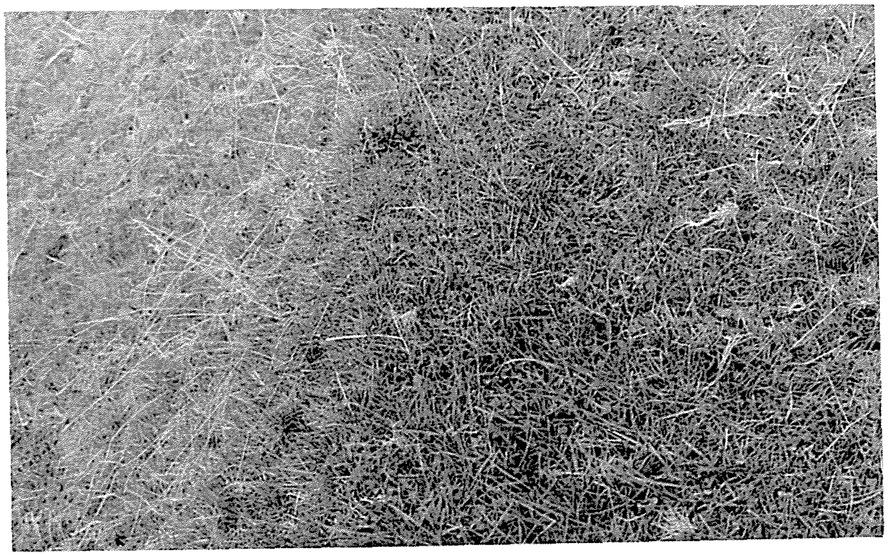

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CHAPTER I. INTRODUCTION and REVIEW:

SIGNIFICANCE OF PATTERN:

An important aspect of the science of plant ecology is the determination of the nature and causes of variation in vegetation. Reflecting the controlling influence of the physical environment, this variation is continuous both in space and in time. The most rewarding means of unravelling the intricate relationships between vegetation and habitat is through the detection and analysis of pattern.

In an ecological context, pattern may be defined as the non-random distribution of vegetation units within a defined area. This means in effect, that the distribution is either more contagious or more regular than could be expected, if chance was the only factor which influenced the distribution. Greig-Smith (1964) described a random distribution as one in which the presence of one individual (unit) does not either raise or lower the probability of another occurring nearby.

The existence of pattern in vegetation is apparently a universal phenomenom. It may be manifest on a very wide range of scales and intensities; from broad global-wide belts of vegetation, down to the variable performance of a single species over a small area. Causes of pattern may be either intrinsic, (e.g. method of dispersion, competitive ability) or extrinsic, (e.g. variations in the effective physical environment).

DEVELOPMENT OF PATTERN STUDIES:

The beginning of plant ecology as a science is frequently fixed near the start of the present century. During the 60 or more years since, a major line of development has been the increasingly precise study of variation of vegetation in relation to variation in the environment, associated with a swing from qualitative to quantitative methods of analysis.

Over the first 30 years valuable contributions towards basic theory and practice were made by many descriptive ecologists. Clements (1928) and many others systematised the knowledge gathered from close observations and wide experience to form concepts generally accepted still. From the start, the Anglo-American school placed a strong emphasis on a combined environmental-vegetation approach. Relationships were appreciated as being intimate and dynamic. The community was seen as a highly integrated entity, which faithfully expressed the conditions of a particular habitat. This formed the basic unit of variation in vegetation, upon which were erected hierarchial systems of classification.

Descriptive mapping remains a valuable aid in the analysis of vegetation, but the application of quantitative methods involving sampling, measurement and the statistical analysis of results, has resulted in a "not-so-simplified" interpretation of pattern. In Greig-Smith's (1964) words, "the quantitative approach, besides allowing for the detection and appreciation of inconspicuous differences, provides suitable statistical tests which allow a sounder judgement of the significance of the observed differences". As a result, emphasis has been increasingly placed on a multi-factorial approach, which recognises that plant distribution is conditioned by interaction between several or many environmental factors capable of independent variation.

When ecologists began sampling vegetation to assess the distribution of species, it quickly became obvious that even within apparently homogeneous vegetation, there was an expectedly high incidence of pattern. (e.g. Blackman 1935, Ashby 1935). Over a period, mathematical models were matched with sets of data, but even with a good correspondence it was difficult to relate statistical and ecological significance. At best, only a guide was given to the scale and possible causes of pattern.

These studies threw into relief the importance of point to point variability. Similarly, on a broader scale, Curtis and McIntosh (1951) later demonstrated the occurrence of a continually shifting compositional gradient of tree species in upland Wisconsin. Each species reached its maximum importance independently and in a definite sequence. Many other compositional continua or ordinations have since been demonstrated, tending to lend support to the opinion of Bray and Curtis (1957) that ... "units of variation should be established statistically and objectively rather than by observation".

CORRELATION WITH HABITAT:

Associated with the increasingly quantitative approach to the analysis of vegetation, was a similar approach to the assessment of those habitat factors judged as being the most critical. Such variables can often be correlated to provide strong evidence on causes of pattern. However, the existence of a correlation is not proof of a causal relationship, since both may be controlled by some over-riding factor. Final proof can only be obtained when all other variables are held constant. Since this situation is generally impracticable in the field, supporting evidence and sound judgement may have to suffice.

Pattern analysis, through the correlation of vegetation and habitat variables, has proved to be highly profitable over a wide range of levels. Some representative examples are given below.

Pattern (1963) assessed a complex mosaic of forest, sage brush and grassland communities over a large area in the Madison Ra. of Montana. Variations in climatic, biotic, pyric, geographic and edaphic factors were studied. Single and multiple correlations revealed that much of the variation could be attributed to differences in water availability, but the whole complex pattern could be understood only in relation to the holocoenotic environment - including past history.

At the other extreme is a study by Kershaw (1958). Using a sensitive contiguous quadrat method, he was able to demonstrate a progressive shift in scale of pattern during the development of a grassland community. From small isolated "invasion centres" there developed a larger scale, found to be caused by the relatively high performance of Agrostis in patches of shallow soil. This intensified into a reticulate pattern, until at the final stabilization phase, the sward became fairly uniform and almost free of pattern.

A similar striking example was given by Chadwick (1960) for the unpalatable grass Nardus stricta. Two scales of pattern were found, the smaller of which at 20 c.m. diam. was due to individual morphology. After measuring plant growth rates, Chadwick concluded that the larger scale at 160 c.m. was due to a gradual centrifugal spread (at a rate of 2 c.m. p.a.) over a 40 year period, following the relaxation of grazing pressure.

The "micro-distribution" of Trifolium repens over a 10 m.sq. area in relation to soil variation was studied by Snaydon (1962). The clover performance, as represented by cover, was tested for significant correlation with a number of soil variables. Snaydon concluded that there was a direct causal relationship between performance and amount of Ca. and P. The significance of point to point variability in soil conditions was emphasised.

Variation within a grass-heath community related to seven stages in a profile development series was described by Watt (1940). Associated with the change from a calcareous clay soil to a mature podzol were significant differences in the type of species contributing to the community.

Harper and Sagar (1953), investigating the ecology of three closely related species of Ranunculus, found after statistical analysis, that each species showed a characteristic relationship to a microtopographical pattern of ridge and furrow. The zonation appeared to be caused by variations in soil moisture and the behaviour of the three species in relation to various moisture regimes was tested in the lab. From the results it was apparent that the balance was caused and maintained the level of soil moisture during the pre-emergence and early seedling stages.

Microtopographical features have been shown to induce pattern in vegetation in a number of other cases. Balme (1953) studying vegetation on carboniferous limestone, reported a distinct community zonation closely related to edaphic zonation over a range of slopes. This sequence he described as a catena. "A group of soil-vegetation types linked in their occurrence by conditions of topography and repeated in a similar relationship to each other where-ever the same conditions occur". Major zones of the catena were obviously demonstrated by the dominant plant species on each. Smaller variations in habitat, particularly those occurring near the limits of the different zones, could sometimes be recognised by the distribution of indicator species.

Many examples of microtopographical pattern imposing a corresponding pattern on the vegetation are reported from alpine and arctic environments. In these extremes conditions even minor variations in some factor such as exposure can show a very marked effect on the vegetation. Distinct and uniform microtopographical patterns are common in arctic and alpine regions where the freezing and thawing of moisture can induce considerable disturbance within the soil. Warren-Wilson (1952) discussed several types of patterned ground occurring on Jan Mayen Is., each one characteristic of a certain steepness of slope. One of the types was a series of solifluction terraces measuring approx. 10 m. wide and 1 - 3 m. high. A slow downward movement of the unstable top soil was resisted by turf and large stones.

Billings and Mark (1961) found hummocks, stripes and terraces in an area of New Zealand's Old Man Range. The terraces varied from several to many meters wide and showed evidence of active movement. Vegetation data, gathered by point analysis enabled five zones to be demarcated, corresponding to variation in water availability and shelter across the terrace unit. The general picture was one of alternation between wind and "drought" tolerant cushion species occurring on the outer edges, with less resistant taller species in the lee of the terrace bank.

Watt and Jones (1948) and Burges (1951) found a similar situation on a terraced area of the Cairngorms. Burges confirmed the initial impressions gained by the previous investigators. Across these broad "mobile" terraces, variation in moisture availability and exposure again appeared to be the most significant components of a factor complex which imposed gradations, in both habitat and community. Even though there existed considerable variability in the form of terraces, the relative positions of the micro-communities remained constant, reflecting on a small scale the pattern of major communities.

Another instance of variation over a series of solifluction terraces on the Bear Tooth Plateau of Wyoming, was described by Johnson and Billings (1962). "Within each vegetation type smaller vegetation patterns develop in response to local disturbance ... Inactive patterned ground perpetuates microhabitats which are of particular importance in such a severe physical environment for the future development of various plant communities."

PATTERN IN THE PASTURE:

The present study is concerned with the effect of a particular microtopographical pattern on a number of grazed pasture communities.

The artificial pasture community offers a potentially fertile source of information from pattern analysis which should throw light on both plant and animal aspects of the grazing complex. Hughes (1955) has demonstrated the possibilities of a quantitative survey approach. The compact but environmentally complex region of Snowdonia in Wales was divided into 55 "sheep walks". By statistical analysis he was able to delegate the variability in stock carrying capacity to ecological factors - in particular, to climate. Nine ecological regions could be defined, between which, significant differences occurred in such factors as climate, soil type and vegetation.

Hunter (1962) similarly demonstrated significant ecological variation through variations in animal grazing pressure. Over a 250 acre area, nine types of community were found to be subject to different grazing intensities by unrestricted sheep. Like Hughes, he stressed the practical value of such ecological studies.

Underlying variations in the local habitat, often caused or intensified by grazing animals, tend to be quickly reflected through changes in the structure and composition of the highly dynamic pasture community. This is particularly so on sloping ground where differential stock behaviour, soil and microclimatic variations present a myriad of microhabitats. Macro - and microtopographical features which are the basic causes of this variation include: bluffs and banks, outcrops and slips, springs, seepages, bumps and hollows, ledges, paths and occassionally logs, stumps and rocks.

Where habitat variation occurs in a characteristic and regular form, there is a greater chance of relating cause and effect. Such a situation is found with the pattern of tracks so typical of grazed slopes. To determine the nature and cause of variation in pastures associated with the microtopographical feature of "sheep paths" is the purpose of the project.

There is scant literature available on this particular topic. Most references to the situation have been made in passing and do not have accompanying data. e.g. Levy (1951) ... "On stock-terraced land, two distinct associations tend to arise - one dominated by grasses where stock tread and excrete, and the other by clovers and lower-fertility-demanding grasses", and Sears (1956) ... "A typical profile across one of these units shows the "step" to have dominant ryegrass with white clover on the outer margins. Weeds are rarely found on such tracks. Up the "riser" areas, the composition changes progressively to clover, browntop, sweet vernal, fog, danthonias, weeds and moss. At the top of the riser areas, there is usually a definite overhanging lip formed by pressure from the track above. Weeds, and species unpalatable at a more mature stage readily establish here".

Thomas (1959) demonstrated a structural and compositional pasture pattern associated with distinct and uniform tracking patterns on four slopes in England. A 10 point, 10" frame was placed every 2" within a 20" x 10' transect, to give 600 points per transect. A graphical illustration of species distributions was presented but no statistical analysis or habitat studies were carried out.

Data on both vegetation and soil variability was presented by During and Radcliffe (1962) for two New Zealand steepland (35°) soils. Slope zones were divided into three categories: tracks, little modified slopes, and steep sidlings. The pasture was classified into three types: (1) medium to high fertility-demanding species, (2) low fertility-demanding species, and (3) a class comprising weeds, moss and bare ground. The order of preference for class (1) was tracks, little modified slopes, steep sidlings; for class (2) it was slopes, sidlings, paths; and for class (3) it was sidlings, slopes, tracks. The results of soil analyses were not so definite, but generally the tracks were moister, contained higher amounts of total C. and total N. and had a lower C/N ratio.

PROJECT OUTLINE:

The aim of the project was to assess the nature and causes of variation in pasture on representative examples of "stock-terraced" slopes.

Information was gathered on three aspects:

(1) The occurrence of "tracking" in relation to soil type and relief, and variation in the form of "track units". From a limited survey data was collected on 22 slopes at 12 well separated sites.

(2) The vegetation pattern associated with well developed "tracking" was quantitatively assessed on five selected sites by point analysis.

(3) Variation in relation to slope of a number of habitat factors was studied at one site.

Experiments were carried out during the summer and autumn of 1965-66.

CHAPTER II. SLOPE SURVEY:

A. INTRODUCTION

An area of about $9\frac{1}{2}$ million acres of grazed North Island hill country is classed as unploughable. These areas characteristically carry what are described as steepland soils (Gibbs 1962), which are distinguished from their counterparts on flat or rolling land by a general shallowness of the A and B horizons and a high degree of local variability.

On sloping ground, gravity subjects the unconsolidated soil mantle to continual downslope movement. This effect intensifies with increasing angle of slope and where stream erosion continually removes material from the base. Movement occurs by three main processes. (1) Soil creep is made up of a continuous succession of minute movements within the soil horizons and results in an imperceptible downslope movement of the whole soil. (2) Sheet wash occurs when particles are carried down over the surface by running water. (3) The third type of movement is massive sliding.

As a result of the relatively rapid loss of soil by these three erosive processes, there is a continual exposure of new material to soil-forming processes, so that the rate of soil turnover is high. The inherent instability of steepland soils may be magnified by such factors as a moist climate and a weakly-coherent parent material. Also, the replacement of forest vegetation by grassland, and the introduction of grazing animals has been accompanied by a partial loss of soil stability in many areas.

Topsoil mobility of steepland soils is generally believed to be the main causal factor in the formation of the widely occurring micro-topographical features known variously as "sheep paths", "cattle tracks", "stock-terraces", "terracecettes" or "milled surfaces". While there is a dearth of precise information regarding the detailed structure and method of formation of these so-called sheep paths, Sharpe (1960) has presented a number of theories on the subject. Apparently they are common on slopes of both stratified and unstratified material, forming as a result of either or both, small-scale geologic processes and animal action. All gradations from miniature fault blocks to true paths occur. The geologic processes include: (1) a gradual slipping of the soil mantle followed by the opening up of cracks running transversely across the slope; (2) an outward rotation of superficial blocks; (3) slump movements resulting from slippage on a deep-seated concave surface. Many examples have been quoted where terracettes form in the absence of grazing animals, but in other areas treading and grazing aids in the development of small slip planes by baring and compressing the soil surface.

There is also little known on the stability of these formations, but Thomas (1959) quoted an example of a path moving 2' down a slight (13°) slope over a four year period.

B. METHODS

At 12 localities (see Fig.II.1) where "tracking patterns" were distinct and regular, traverses were run down 22 slopes to provide information on the dimensions, form and variability of the track units (one unit encompassing the ground between successive tracks). The number of units covered varied according to local conditions, but on each slope, two traverses, spaced about 10 yards apart, were made.

A tape measure, pegged at one end was firstly pulled tight, the distance between the outer edges of successive paths noted, and the overall angle of slope measured with an Abney level. Then with a slackened tape, the widths and surface steepness of the major slope zones were measured.

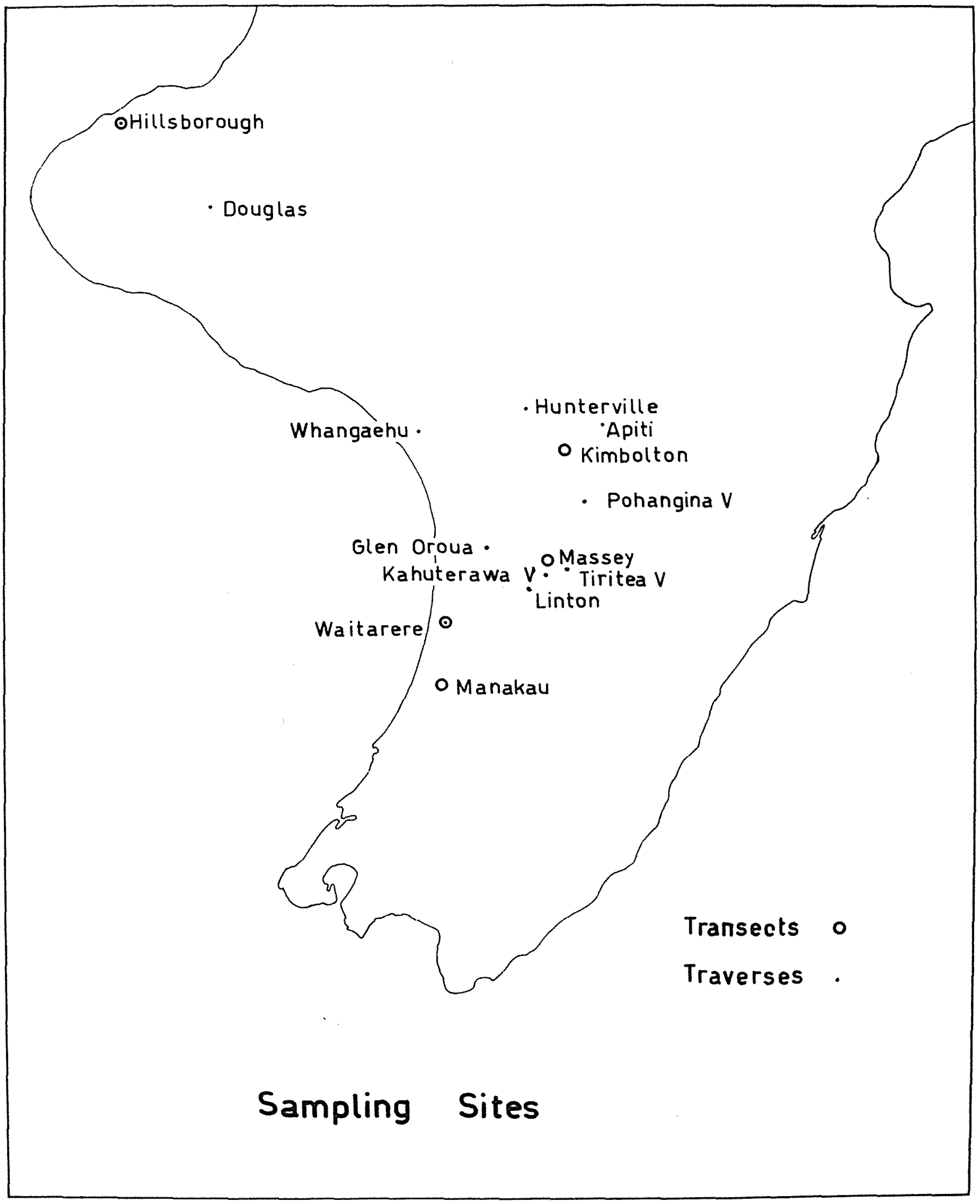


Fig.II.1 Location of Sites Sampled by Traverse and Transect

Note was taken of the pasture composition at each location, whether there was evidence of pattern and the type of grazing management.

Photographs of some of the sites appear in Figs. II.2 - 3.

The Microtopographical Pattern Generally

Referred to as "Sheep Paths".

C. RESULTS

Site information and data appears in Tables II.1 and II.2

TABLE II.1 TRAVERSES - General Information

Site	Soil Type	Management	Pasture Type	Pattern
Hillsborough	N.Plymth sandy loam on free loam - stable and free draining.	Breeding sheep and cattle	Ryegrass - white clover & sw.vernal - browntop	Obvious
Douglas	N.Plymth sandy loam hillsoil	Dairying	White clover - ryegrass and sw.vernal	Not obvious
Wangaehu	Atua silt loam on clay loam	Breeding sheep and cattle	Sw.vernal - browntop - cr.dogstail	Not obvious
Hunterville	Atua silt loam on clay loam	Breeding sheep and cattle	Browntop - sw.vernal	Not obvious
Apiti	Kiwitea loam hillsoil on silt loam	Breeding sheep and cattle	Browntop - sw. vernal	Obvious
Pohangina V.	Ohakea loam on clay loam	Breeding sheep	Browntop - sw.vernal - cr.dogstail	Not obvious
Tiritea V.	Tokomaru heavy silt loam on clay loam	Breeding Sheep and cattle	Sw.vernal - browntop - cr.dogstail	Not obvious
Massey	Tokomaru silt loam on clay loam	Dry sheep and cattle	Browntop - ryegrass - white clover	Obvious
Kahuterawa Valley	Makaha stony loam on stony silt loam	Dry and breeding sheep and cattle	Sw.vernal - browntop	Very obvious
Tokomaru	Tokomaru silt loam on clay loam	Dairying	Sw.vernal - white clover - browntop	Very obvious
Glen Oroua	Patea sand (consolidated)	Dairying	Sw.vernal - browntop - white clover	Not obvious
Waitarere	Patea sand	Breeding sheep	Sw.vernal - browntop - white clover	Obvious

TABLE II.2 TRAVERSES - Physical Data

Sites	Overall Slope °	No. of Units	Slope Dist.	Interval between Units (' - ")			Width of Slope Zones (")				
				Oblique	CV%	Vertical	Total	Path	Kerb	Bank	Slop
Hillsborough	25-30										
A.		9	47-0	5-3	4.4	2-6	84	20	8	10	46
B.		9	40-11	4-7	6.7	1-11	81	18	8	9	46
C.		7	32-6	4-8	6.6	1-11	86	20	6	9	51
D.		6	30-11	5-2	5.4	2-4	87	19	7	9	52
Douglas	30-35	13	65-6	5-0	4.3	2-10	87	15	-	10	62
Wangaehu	30-35										
A.		8	32-9	4-1	7.7	2-1	76	15	-	6	55
B.		8	34-0	4-3	7.2	2-5	79	15	-	8	56
Hunterville	30-35										
A.		6	26-6	4-5	5.9	2-6	71	16	-	8	47
B.		8	34-9	4-4	6.5	2-5	76	15	-	8	53
Apiti	25-30										
A.		5	10-1	4-4	7.0	2-4	64	15	-	6	43
B.		7	28-0	4-0	6.3	2-1	62	15	-	7	40
Pohangina V.	30-35										
A.		6	25-1	4-2	8.2	2-5	73	18	-	12	43
B.		9	40-5	4-6	8.9	2-6	77	17	-	12	48
Tiritea V.	20-25										
A.		3	12-8	4-3	4.1	2-0	73	18	-	10	45
B.		4	16-7	4-2	4.4	1-6	69	15	-	9	44
Massey	25-30										
A.		7	25-11	3-8	6.1	1-10	63	15	-	9	39
B.		7	28-3	4-0	5.6	2-1	67	16	-	11	40
Kahuterawa V.	35-40	10	45-9	4-7	8.0	2-10	84	14	5	13	52
Tokomaru	30-35										
A.		6	32-9	5-5	1.2	2-9	68	15	-	7	46
B.		7	40-2	5-9	1.7	2-10	73	15	-	6	52
Glen Oroua	20-25	5	21-4	4-3	3.7	2-2	64	12	-	5	47
Waitarere	25-30	6	26-11	4-6	3.5	1-10	62	18	-	7	37

D. DISCUSSION

Tracking patterns occur quite commonly but it was not easy to locate sites where a regular pattern occurred over a reasonably large area. Interlocking paths were far more frequent than parallel and where the latter did appear, they were often confined to a small area and encompassed only a few units.

The sites finally selected for measurement, included a wide range of soil types:- consolidated sands, sandy loams, stony loams, loams and silt loams. Apparently distinct tracking was not confined to any particular textural class, although it was noticeable that the most regular and extensive patterns were found on relatively stable soils, i.e. the free-draining sandy loam at Hillsborough and the stony loams at Manakau and in the Kahuterawa Valley. At these sites, the paths were typically level and were bounded on the outer edge by a raised (2-3") "kerb". (See Fig.II.3).

Whether the grazing stock was predominantly sheep or predominantly cattle, or whether the stocking rate was high or low, did not seem to affect either the occurrence or form of tracking patterns.

A variety of pasture types were encountered. The occurrence of obvious pattern in the pasture appeared to be more dependent on the form of the unit than on any other factor. It tended to be less obvious on less distinctly formed units. Wherever pattern did appear it was more of a quantitative than qualitative nature.

The overall steepness of the slopes ranged between 20 and 40° with the majority lying between 25 and 35°.

Some significant points are illustrated by this table although the general conclusions which can be drawn are limited. The dimensions of only 156 units on 22 slopes were measured and furthermore, sampling was restricted to uniform areas.

TABLE II.3 UNIT DIMENSIONS IN RELATION TO STEEPNESS

General Slope Classes	No. of Slopes	Mean width per Unit (' - ")		
		Oblique	Vertical	Surface
20° - 25°	3	4-3	1-10	5-9
25° - 30°	9	4-5	2-1	6-1
30° - 35°	9	4-8	2-6	6-6
35° - 40°	1	4-7	2-10	7-0

There was a 20° difference in steepness between the four classes yet there was surprisingly little difference in average unit widths. The oblique distance means (i.e. from path edge to path edge) differed by a maximum of only 5". Vertical interval means showed a small progressive increase with steepness. The 5° increase in overall slope was equivalent to a 4" increase in vertical interval. A similar small, yet progressive increase in unit surface width was shown with increasing steepness.

Not only were unit dimensions rather similar over the whole range of sites, but also the general form. At the outset it was decided to subdivide units into three or four physiographic zones which appeared consistently on all well-formed track units. The mean dimensions of these zones appear in Table II.2.

The PATH zone generally sloped outwards at an angle of about 10° (occasionally reaching 20°). Where a kerb occurred along the outer edge the path tended to be nearly level. Width means differed by a maximum of 6" (14-20") and had an overall average of 16".

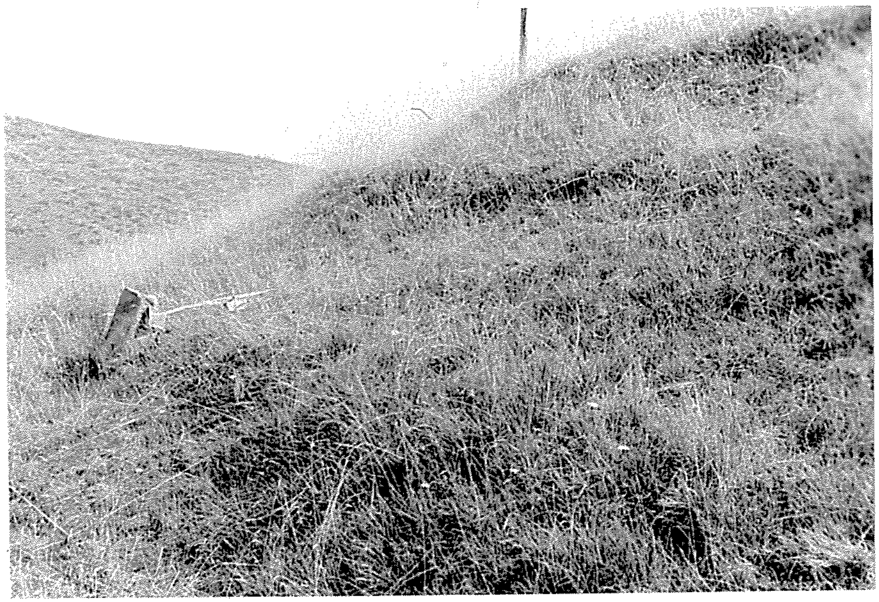
The KERB zone occurred only on a few sites where it was raised about 2-3" above the path and measured 3-6" across the level top.

The BANK zone sloped away from the path at 50 - 90° angles. The overall average width was 9" but site means ranged between 5 and 13".

The SLOPE zone lay between 20 and 50°. This was invariably the widest but it was quite variable. The range encountered between sites was 25" (37 - 62"), with an overall average of 47".

The form of track units varied between sites in a manner which implies that both relief and soil type could be of significance. Bates (1951) has suggested that units become more distinct and more numerous as steepness increases, and there is some evidence to support this here. However it seems that soil texture may be of greater importance. The least well-developed units were found on the sandy soils at Glen Oroua and Waitarere and the most well-developed on the coaser loams at Hillsborough, Manakau and in the Kahuterawa Valley. Units on the heavier soil types tended to be intermediate in form. It was noticeable that tracking was more distinct on the convex "spurs" rather than in the "valleys" between.

Unit scale diagrams in Figs. II.4 and II.5 show a range of forms in which there is a progressive increase in slope differences between zones.



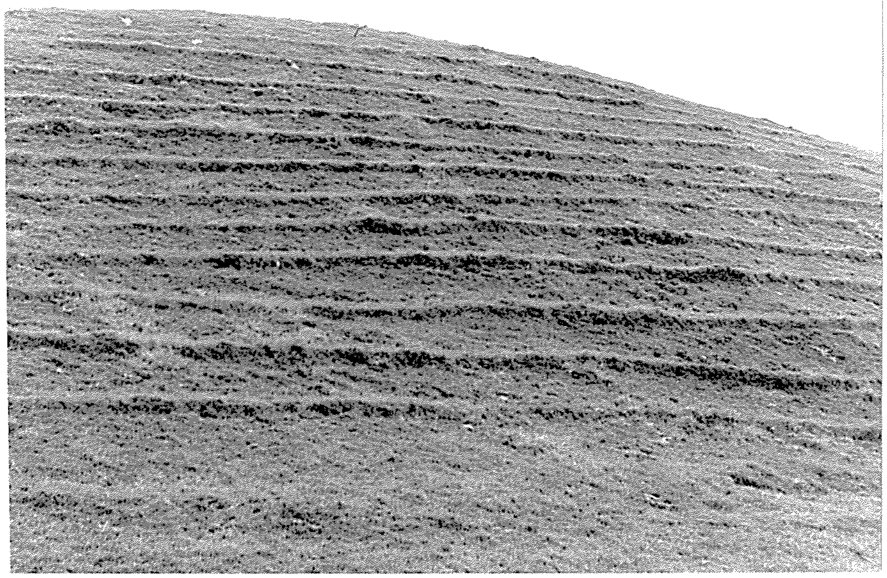


Fig. II.2 Sites Sampled by Traverse

Weakly-developed Units at Glen Oroua (upper) and

Well-developed Units at Douglas (lower).

Fig. II. 3 Sites Sampled by Transect.

Kimbolton (upper) and Hillsborough (lower)

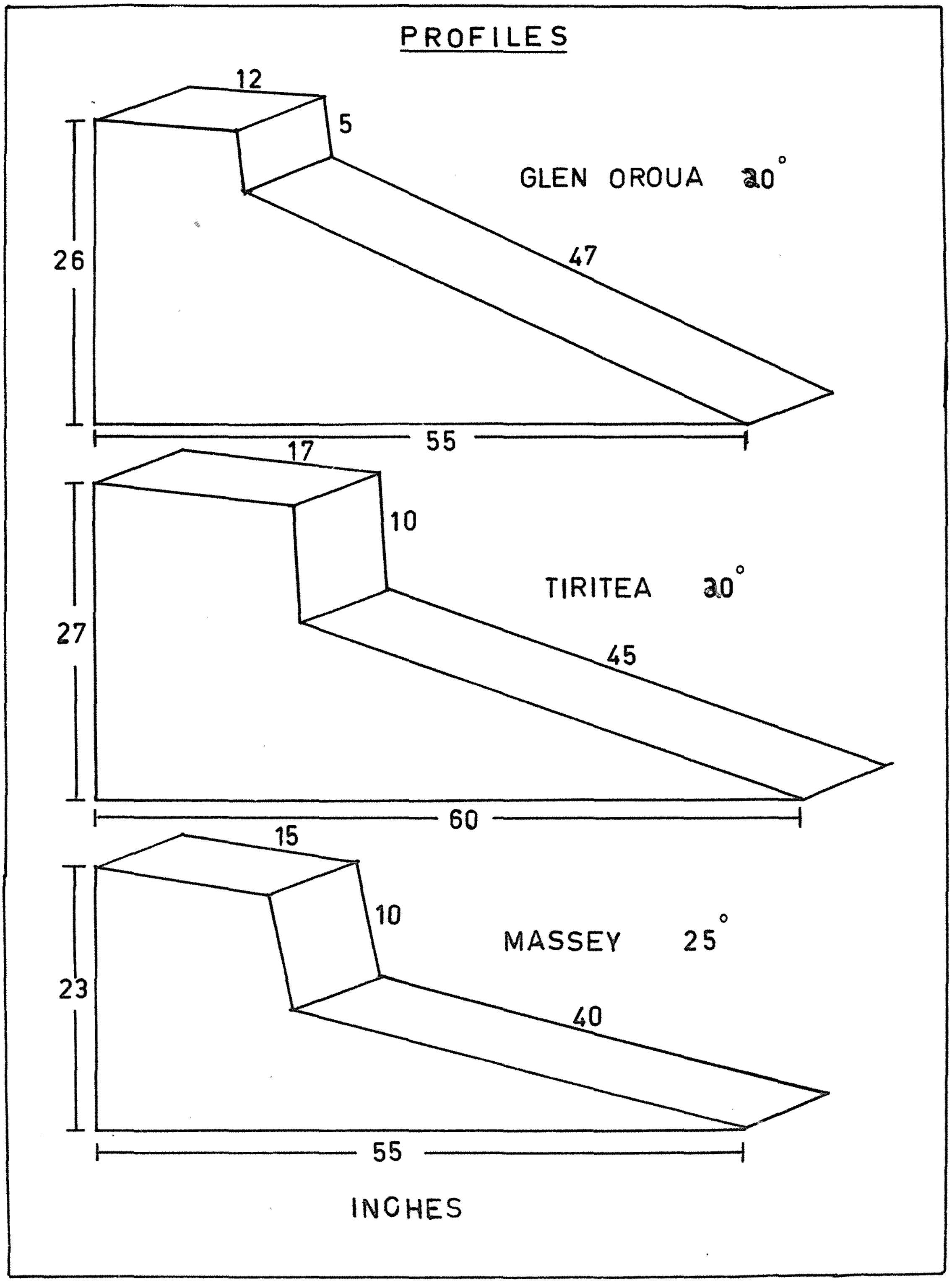


Fig. II.4 Form of Units to Scale (Site Average)

(a) Relatively Poor Development on

Light and Heavy Textured Soils

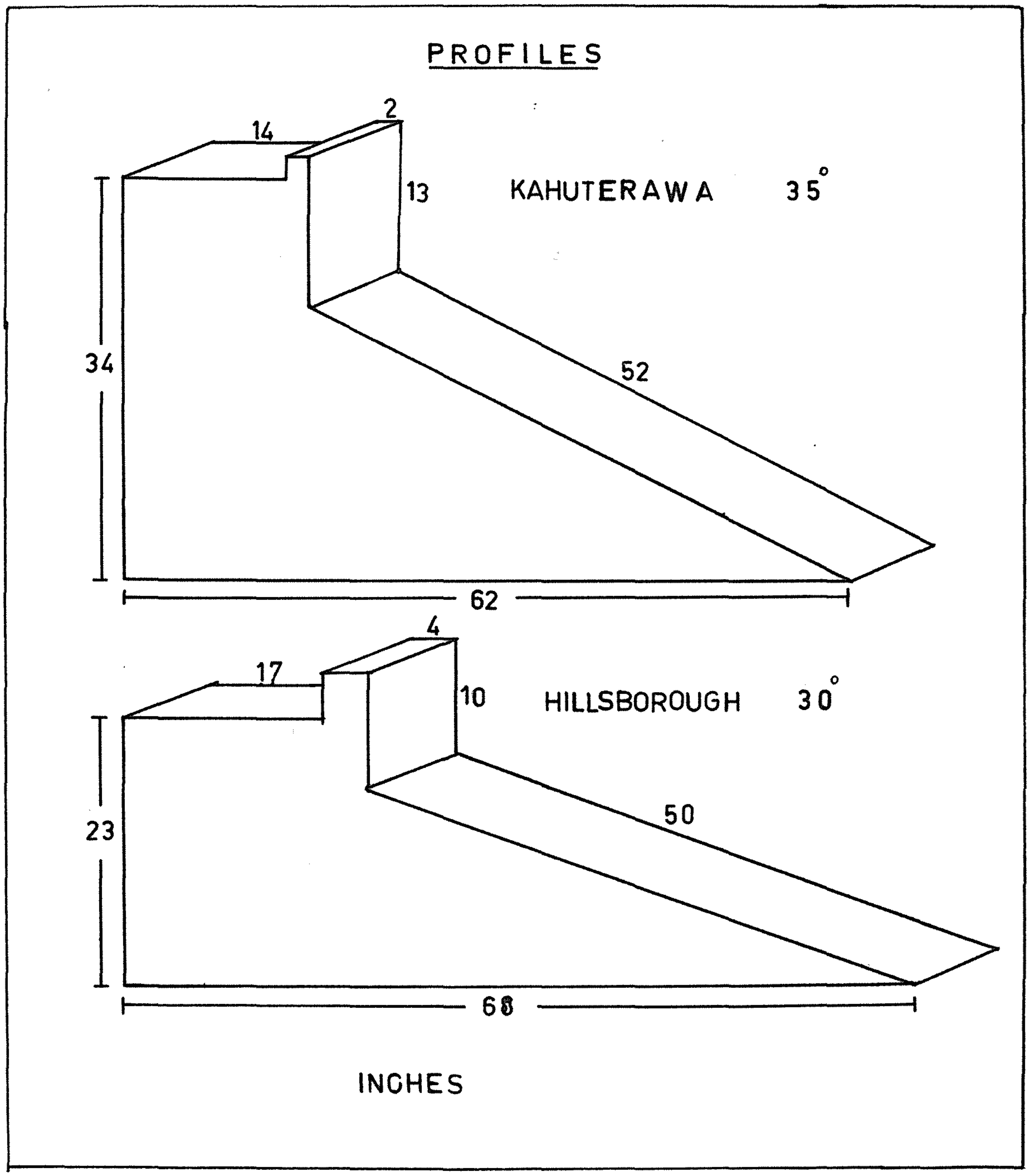


Fig. II. 5 Form of Units to Scale (Site Average)

(b) Relatively Good Development on

Medium Textured Soils.

CHAPTER III. PASTURE ANALYSES:

A. INTRODUCTION

It was postulated that well-grazed slopes having regular patterns of "sheep paths", showed also, corresponding patterns in pasture composition and structure which thus reflected significant variations in the habitat.

Information was required on a number of aspects:-

(1) The overall pasture composition.

(2) The distribution of individual species within the pasture community.

(3) The combination (or otherwise) of these distributions to form microcommunities.

(4) The correspondence between regular variation in the pasture and ground surface configeration.

Small distances were involved in this study of pattern, hence it was a great advantage to have the pasture as short and as even as was practical. Accordingly, sampling was carried out after heavy grazing. Sometimes additional trimming with hand clippers was done to get a uniformly low height.

Uniformity and regularity of track units were important criteria in site selection. This was in accordance with the advice of Greig-Smith (1964), that ... "The selection of the site or type of vegetation to be examined in detail (in contrast to the positioning of samples within it) must be made subjectively, and the success or failure of the investigation may be decided by this selection".

It was considered that variation would best be illustrated by assessing progressive changes in the relative abundance of all species along strips laid parallel to the general slope. If small contiguous sampling units were used then they could be grouped for comparison according to scale of pattern.

In the following pages a few terms such as "species preference" and "species avoidance" are used. The anthropomorphic connotations of these phrases are appreciated but their useage seems justified on occasions on the grounds of convenience. Where used, they are not meant to imply deliberate plant selection.

B. METHODS & MATERIALS

(i) Site Selection

Five sites were selected for the analysis of pattern in the pasture. All showed distinct and uniform tracking on each slope and all were heavily grazed by sheep prior to sampling, so that pastures generally were below 2" in height. Sites otherwise varied in location, relief and soil type. Each had a sunny and a shady aspect which with one exception were included within the same paddock. In addition, two were pegged, to be re-sampled after a four monthly interval. Data were collected from transects deliberately placed on the most suitable areas and lay parallel to the direction of slope.

The location of the sites is shown in Fig.II.1 and some information appears in Table III.1.

TABLE III.1 SITES - Physical Comparisons

Site	Location	Soil Type	Management	Aspect	Slope°	No.of Transect
Hillsborough (New Plymouth)	Inglewood N.109 702.888	New Plymth.sandy loam. Med. fert. free draining	Breeding sheep, some cattle	Sunny Shady	30-35 30-35	2 2
Massey (Palmerston North)	Palm.Nth N.149 093.303	Tokomaru silt loam. Med.fert. Slow draining	Dry sheep and cattle	Sunny Shady	25-30 25-30	2 2
Waitarere (Foxton)	Levin N.152 795.125	Patea sand. Low to med. fert. Free draining	Breeding sheep	Sunny Shady	25-30 25-30	1 1
Kimbolton (Feilding)	Mangaweka N.139	Kiwitea loam Med. fert. Free draining	Breeding sheep and cattle	Sunny Shady	30-35 35-40	1 1
Manakau (Otaki)	Otaki N.157 718.892	Makaha stony loam. Low to med. fert. Free draining	Dry sheep and cattle	Sunny Shady	35-45 35-45	1 1

Aspects:	Sunny	NE - NW
	Shady	SE - SW
Map Location:	N.Z. Topographical Series.	

(ii) Sampling

Of the absolute measures of a plant community, cover was chosen as the most suitable. With regard to density, the definition of plant units for creeping and tillering growth forms is difficult and rather arbitrary in a dense pasture. Also, comparisons between species of different growth form are meaningless. Yield determinations offer probably the most precise comparisons but involve difficulties in the harvesting of low growing species such as flatweeds and moss and laborious herbage dissection in the lab. afterwards.

For short, dense pasture comparisons of cover as assessed by point analysis, is relatively efficient in terms of both time and accuracy. The method has the advantage of being non-destructive and, as well as composition, can give some indication of community structure if bare ground and degree of layering (cover repetition) are noted. The main disadvantage of cover as a community parameter is the lack of correlation between cover and yield when various growth forms are being compared.

In this experiment while point analysis was used to assess cover, points were taken normal to the ground surface. The parameter measured therefore was not cover in the usual sense, where points are taken vertically. This "surface cover" provides more meaningful comparisons between level and steeply sloping surfaces. All hits were recorded to give absolute and relative values for all species.

On account of both theoretical and practical soundness, point analysis has become a popular technique to assess community composition and structure since first used and described by Levy and Madden (1933). Many modifications to the design of apparatus and treatment of data have since been suggested to improve its efficiency in pasture and to extend its use to other types of vegetation. The most substantial contribution has come from Goodall (1952). Amongst other things, he demonstrated the inaccuracies caused by thick "points" and through the grouping of pins into frames. To assess the importance of variability within a sampling area as well as to compare sampling areas, he suggested that randomisation should be restricted such as to allow sub-areas to be compared.

The point analysers available were designed for flat land and were too rigid and unweildy for slopes that could vary from 0 to 90°.

After trials with various types, an instrument was designed and constructed (modelled on apparatus made by Radcliffe and Mountier (1964)), which was suited to use on slopes. Emphasis was placed on practicability and quality (stainless steel and brass). The apparatus was compact and rigid with adjustable pointed legs and three closely-fitting spring-loaded rods each containing a $1\frac{1}{2}$" needle. These were spaced far enough apart to be considered biologically independent in the short pasture being analysed. (See Fig.III.1).

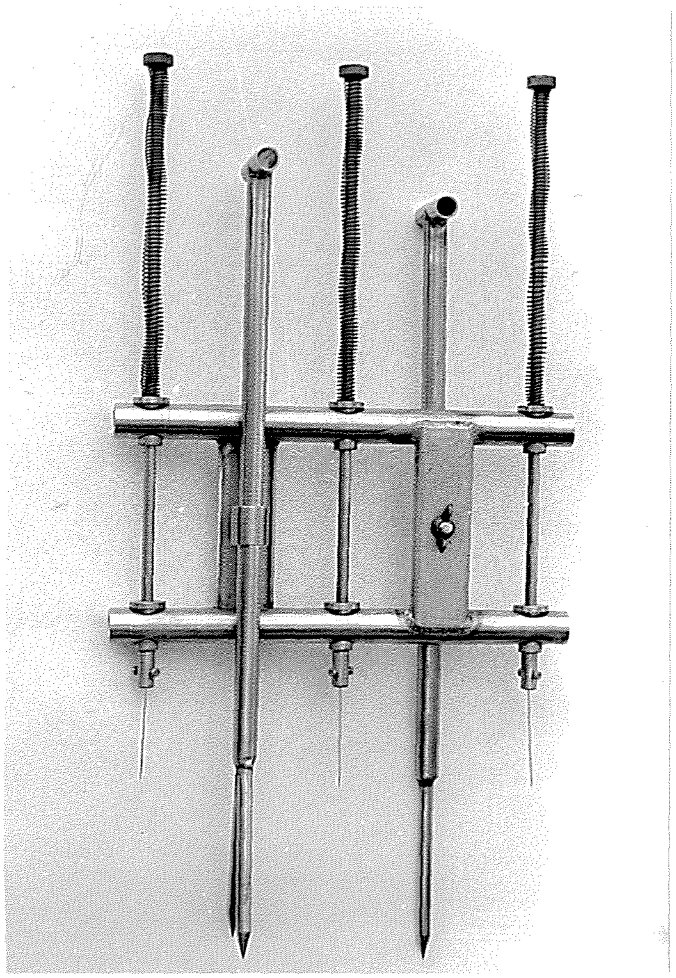
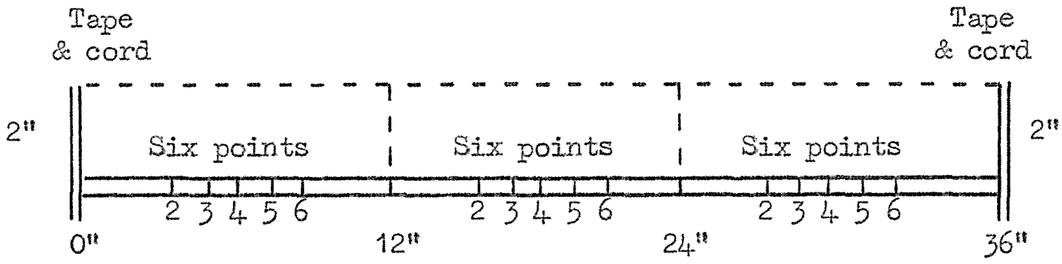


Fig. III.1 Equipment Designed for Point Analysis of Sloping Ground

The transects were 36" wide and long enough to encompass three complete slope units (i.e. path, kerb, bank, slope x 3). Pegged and bounded by cord, each was composed of 2" x 36" contiguous quadrats. Within these, 18 points (6 frames) were taken at random in the following way.



Connecting the cord bounding each side of the transect was 3' of flexible, white plastic-coated curtain wire marked as illustrated. From a card containing a random assortment of digits (from 2 - 6), two were taken for each 12" width of quadrat and the single leg of the apparatus placed on each. Because the quadrat was made narrow, there was no apparent need to randomise in the other direction.

Groups of 18 points were recorded separately as sampling proceeded up the slope. At the same time the major changes of slope were noted so that slope zones could later be separated. This progressive sampling gave raw data which could be set out so that the array of types and intensities of specific pattern could be studied. The "preference for" or "avoidance of" each species for certain slope zones could be noted and if sufficiently exaggerated could be tested statistically. Patterns of species could be combined to see whether the vegetation as a whole varied in a continuous or more or less abrupt fashion with the boundaries corresponding to major changes in slope. Since three sets of slope zones were assessed, the two essential requirements of statistical testing - randomisation and replication - would be satisfied.

Following Goodall's (1952) suggestion resampling on two sites was carried out as closely as possible within the same areas.

C. PRELIMINARY TRIALS

These were carried out on plots at the Massey site during August 1965, to answer two main problems. Firstly, what sampling intensity was required, and secondly, what was the relationship between the parameters of cover and yield for different growth forms?

(i) Sampling Intensity

The selection of how many points are to be taken must necessarily be a compromise between time and effort available and the desired level of accuracy. In the words of Goodall (1952) "The number of points required to give a trustworthy analysis of vegetation ..... will depend not only on the degree of precision required, but will vary from species to species. The question can be answered only in relation to the particular problem and the particular type of vegetation involved".

The Massey site was used to obtain an indication of the intensity of pattern likely to be found. Not only was this area convenient but pattern was likely to be less intense here because of the heavy soil and less well-developed units. A sampling intensity adequate to detect pattern on this site therefore should be sufficient for other areas.

Both sunny and shady faces were analysed with 540 points over three plots. The 180 per plot were allocated equally between path, bank and slope zones. The per centage contribution of each species to the total surface cover was calculated for each slope zone. (See Appendix Table 16).

TABLE III.2 SPECIES DIFFERENCES BETWEEN ZONES

Species	d_1	d_2	N. @ .05		d_1	d_2	N. @ .05	
Browntop	10.5	18.3	200	50	4.7	19.0	900	50
P. ryegrass	3.7	35.7	400	50	3.1	31.8	650	50
S. vernal	2.1	3.0	1000	1000	3.0	3.2	950	1000
Y. fog	2.0	8.0	850	150	2.2	7.2	600	150
C. dogstail	0.9	1.9	1000	950	0.2	0.3	1000	
Cocksfoot	1.4	1.5	600	1000	2.2	2.8	500	550
Notodanthonia spp.	0.2	1.5	1000	750	0	1.0		900
Poa annua	1.5	2.5	650	200	0.7	4.1	1000	300
White clover	3.0	14.1	800	100	1.5	17.3	1000	100
Hawkbit	3.7	4.0	550	600	2.3	4.6	1000	450
Plantain	0.4	1.8	1000	850	0.1	0.4	1000	
Catsear	1.3	1.4	750	1000	0.8	1.1	1000	
Selfheal	1.1	2.8	1000	450	1.8	2.2	750	800
Moss	4.6	5.1	200	300	5.1	5.7	200	300
Bare	0.3	0.4	1000		0.3	0.3	1000	

$$N = 9\,\frac{(\%\,(100-\%)}{d^2}$$

d1 - smallest diff. between communities

d2 - largest diff. between communities

From these results it was concluded that major species showed consistent variation in abundance between zones. In these cases 200 points per community detected significant differences. For minor species or where differences are not so marked, between 200 and 1000 points were necessary. On this basis it was decided to take 300 - 500 points per community type.

Since the number of points varied with the width of the zone, there was a tendency to under-sample the narrowest and over-sample the widest. A sampling intensity of 18 points per quadrat seemed a suitable compromise and this number was fixed for all transects.

(ii) Comparison of Cover and Yield

One path and one slope community measuring respectively 18" x 72" and 36" x 36", were pegged on each face and assessed with 250 points. Following this, communities were closely clipped and a herbage dissection was carried out by the Department of Agriculture lab. (See Appendix Table 17).

TABLE III.3 COMPARISON OF YIELD AND COVER FOR MAIN GROWTH FORMS

SPECIES	Sunny		Shady	
	Path	Slope	Path	Slope
Total Grasses				
% Yield	95.9	85.1	91.8	80.1
% Cover	67.6	58.9	58.0	50.4
Total Clovers				
% Yield	4.1	3.0	6.1	3.8
% Cover	23.2	9.2	22.2	11.5
Total Weeds				
% Yield	T	11.9	2.1	16.0
% Cover	9.3	31.4	19.8	38.0

Differences in growth form had a very marked effect on composition measured by yield and by surface cover. The bulk of erect grasses was substantially under estimated by cover and that of the horizontally disposed clovers, weeds and moss exaggerated. Hence it should be realised that composition as referred to in this study bears little relationship to relative yields.

However for the purposes of pattern analysis the substantial departure between composition by cover and composition by yield is of little consequence.

D. MAIN TRIAL RESULTS

The 14 transects were sampled between November 1965 and April 1966. Data in the form of total hits on all species (and bare ground) were laid out as collected to show variations in the abundance of each along the transect. The correspondence of variation in vegetation and in slope was obvious in all transects. Therefore quadrats in each slope zone were grouped and the percentage of sward values for each species calculated.

i.e. $$\frac{\text{No. of hits on a species}}{\text{Total no. of hits}} \times 100$$

In addition, percentage bare ground,

i.e. $$\frac{\text{No. of times no vegetation was hit}}{\text{Total no. of points}} \times 100$$

and cover repetition,

i.e. $$\frac{\text{Total no. of hits}}{\text{Total no. of points}} \times 100$$

were calculated for each zone.

The percentage of sward measure was considered to give the best indication of the changing importance of a species and comparisons between different species, as it is relatively insensitive to variation in pasture density. These can be picked up from changes in bare ground values and cover repetition. For instance, Radcliffe and Mountier (1964) showed the large effect of slightly different pasture heights on "cover hits" (Total hits per 100 points.

The bulk of the transect data appears in the Appendix. Tables 1 - 14.

(i) Transect Comparisons

TABLE III.4 TRANSECT AND SITE COMPARISONS

	Hillsb.Nov.		March		Massey Dec.		April		Waitarere		Kimbolton		Manakau	
	Sun	Sdy	Sun	Sdy	Sun	Sdy	Sun	Sdy	Sun	Sdy	Sun	Sdy	Sun	Sdy
Length('-")	18-8	19-10			14-6	13-10			15-4	14-2	13-4	15-0	18-0	18-2
Quadrats														
Path	30	32			24	27			20	18	23	24	17	21
Kerb	12	10			-	-			-	-	-	-	6	7
Bank	14	15			14	13			14	14	14	18	19	25
Slope	56	62			49	43			58	53	43	48	66	56
TOTAL	112	119			87	83			92	85	80	90	108	109
Transects														
Points	2016	2142			1566	1594			1656	1530	1440	1620	1944	1962
Hits	3402	3704	3160	3448	2647	2396	2555	2408	2032	1985	1801	2326	1907	2741
Cover Rep	1.69	1.73	1.57	1.63	1.69	1.60	1.63	1.54	1.23	1.30	1.25	1.44	1.50	1.40
Bare %	12.0	8.3	14.0	11.9	8.9	9.2	9.5	11.0	13.4	12.8	14.6	10.8	14.5	14.8
Composition (%)														
No. of spp	28	28	26	27	26	26	26	27	18	23	18	24	20	28
Browntop	10	7	15	11	21	20	25	24	31	27	19	15	38	35
Ryegrass	22	25	19	22	17	16	15	14	9	11	1	2	2	4
S. Vernal	14	11	10	10	12	15	9	12	13	16	37	32	17	20
White clover	9	8	12	11	13	13	15	15	8	11	6	7	7	6
Hawkbit	3	3	4	4	5	5	7	6	8	6	7	6	9	8
Moss	5	6	3	6	5	5	3	4	1	3	3	7	1	2

Since the transects formed a limited sample of the whole slope, they could not be considered representative of their sites. Comparisons between them therefore, are broad rather than precise.

All pastures comprise a wide variety of growth forms and a diversity of species. In general there is a lack of clear-cut dominance by any species and a rather surprising overall similarity of species present. On the basis of overall composition and structure there seem to be two groups of transects. The sites at Hillsborough and Massey constitute Group I which in comparison to Group II (Waitarere, Kimbolton and Manakau) have a wider diversity of species within which perennial ryegrass (Lolium perenne), and white clover (Trifolium repens) assume more important roles; and a greater densness as indicated by the lower proportion of bare ground and the higher values of cover repetition. Group I transects were located on opposing faces of shallow valleys. Differences between sunny and shady aspects were less prounounced than at the other sites where transects were located on opposite slopes of a dune, hill or spur. Browntop (Agrostis tenuis), sweet vernal (Anthoxanthum odoratum) and hawkbit (Leontodon taraxacoides) were more prominent in these latter areas.

(a) The Hillsborough site under relatively heavy grazing and an annual K-super dressing of 1 cwt/ac. supported a well-mixed perennial ryegrass dominated pasture with about equal contributions from sweet vernal, white clover and browntop. Yorkshire fog (Holcus lanatus) and moss (Thiudium furfurosum) were prominent, while narrow-leaved plantain (Plantago lanceolata) was the chief flatweed. While essentially similar on both aspects, slightly higher proportions of perennial ryegrass, fog, plantain and moss on the shady face were balanced by more browntop, sweet vernal and white clover on the sunny side. Changes during the 4-month period are not striking. Apparently there was a small expansion of browntop (Festuca rubra, var. commutata), cocksfoot (Dactylis glomerata) and white clover at the expense of perennial ryegrass, sweet vernal, crested dogstail (Cynosurus cristatus), Poa annua and moss.

(b) The heavy silt loam at the Massey site was under moderate stocking, being used mainly as a run-off. The soil tends to become water-logged during winter but quite dry over summer. Here browntop contributed the majority of cover but perennial ryegrass and white clover were important sub-dominants. Sweet vernal and Yorkshire fog were of lesser importance while hawkbit and moss each contributed about 5%. Again, the pastures on opposing faces were essentially alike with similar small differences in species abundance. During the period December to April, the cover of browntop and white clover expanded while pennyroyal (Mentha pulegium) and bidibid (Acaena anserinifolia) appeared in detectable quantities. Perennial Ryegrass, sweet vernal and moss again showed a slight decline over summer.

(c) The low (50') sand-dunes at Waitarere supported more diverse pasture types on sunny vs. shady aspects. Species such as chewings fescue, browntop, Notodanthonias, ratstail (Sporobolus capensis) and flatweeds were more abundant on the sunny side. On the other hand perennial ryegrass, sweet vernal, white clover and moss appeared more on the shady aspect.

(d) On the two remaining sites perennial ryegrass played a minor role while the dominance of browntop and sweet vernal became more pronounced. Unlike Waitarere or Hillsborough neither receive consistent topdressing. Both soil types are free draining and of low to medium natural fertility. At Kimbolton, the shady pasture was richer in species and denser in structure than the sunny. Differences in species abundance were consistent with Waitarere.

(e) The site at Manakau, occupying an elevated and exposed spur was the only one where a fence separate the two aspects so that stocking treatments may have been different. The proportions of bare ground recorded were similar, but the sunny face had higher cover repetition values due to longer pasture. Aspects differed by only 90° (NW and SW) and although composition differences followed a pattern similar to other sites, they were not as pronounced as might be expected.

(ii) Pattern Within Transects

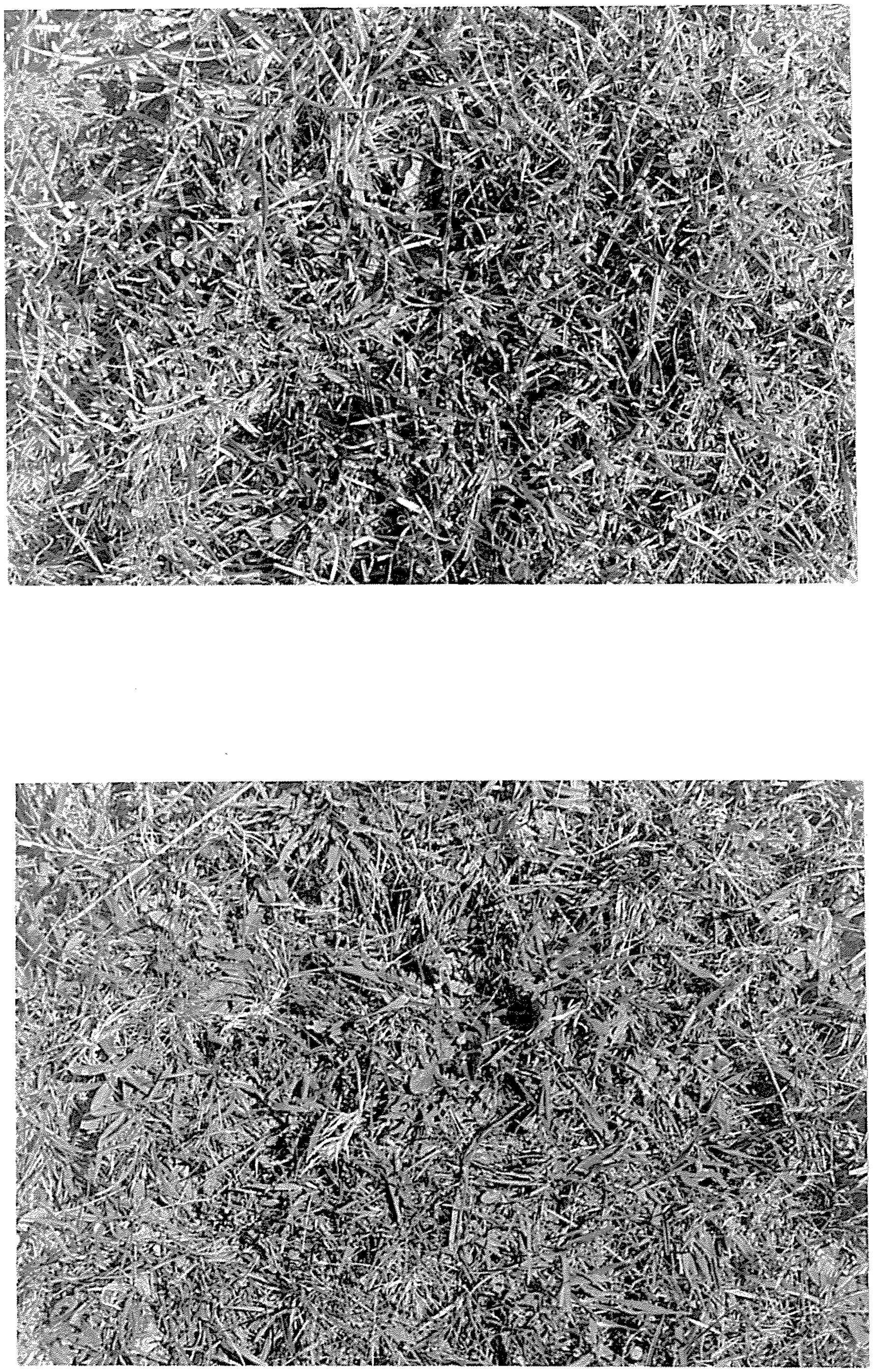
(a) Growth Form Patterns -

All transects showed distinct internal pattern in a high proportion of species. These were of different intensities and either quantitative or qualitative.

After inspection, transects were sub-divided and major slope zones or habitats were separated for comparison. According to the surface configuration there were either three or four habitat types which were termed path, kerb, bank and slope. The relative abundance of each species in each of the 9-12 zones was calculated.

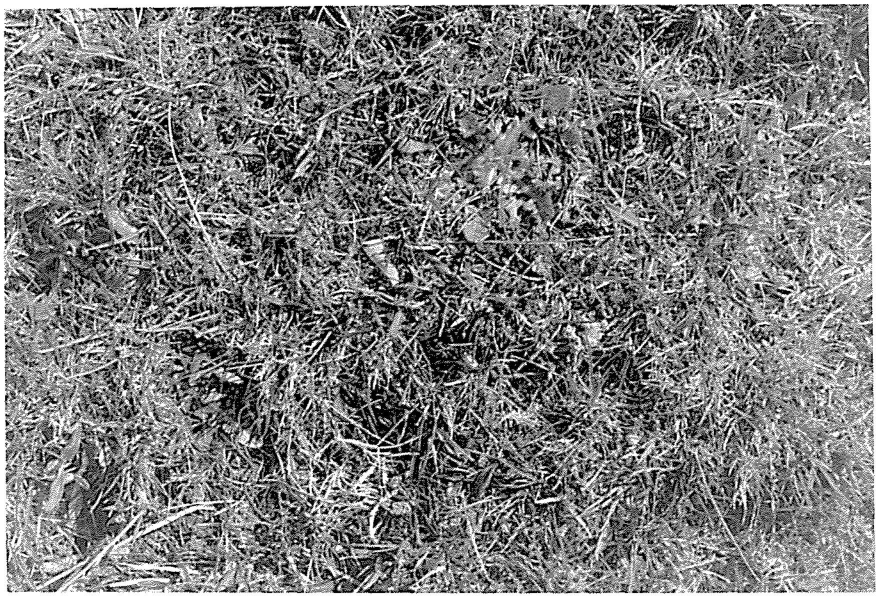
Figs.III 4, 5 illustrate the average relative dimensions of the slope zones for each site. Species are classified according to growth form into grasses, clovers, weeds or moss to illustrate a consistent growth form pattern.

Fig. III.2 Surface Configuration at Hillsborough (path, kerb, bank, slope) and Massey (path, bank, slope).



Typical Appearance of Path (upper) and Slope (lower) Microcommunities on Transect Sites

(a) Hillsborough.



(b) Massey.

Grass was the dominant form in all habitats, contributing between 52 and 88% of the total cover. Its relative contribution to yield must have been substantially greater. In general the dominance of grasses was most pronounced on paths, although at the Massey site, there was a slightly higher proportion of grass covering the steep bank.

The clover cover ranged from 4 to 23%. It was more variable between sites, showing, for instance, a fairly uniform distribution at Hillsborough, a distinct inclination for the paths at Massey and a variable distribution at other sites where annual clovers confused the pattern of white clover.

The picture of weed distribution was a consistent one of increasing abundance in the following order of slope zones; path to kerb to bank to slope. Cover values ranged from 6 to 28%, the majority of it coming from flatweeds.

Similarly, moss showed a consistent picture of greater abundance in the order path to bank to slope.

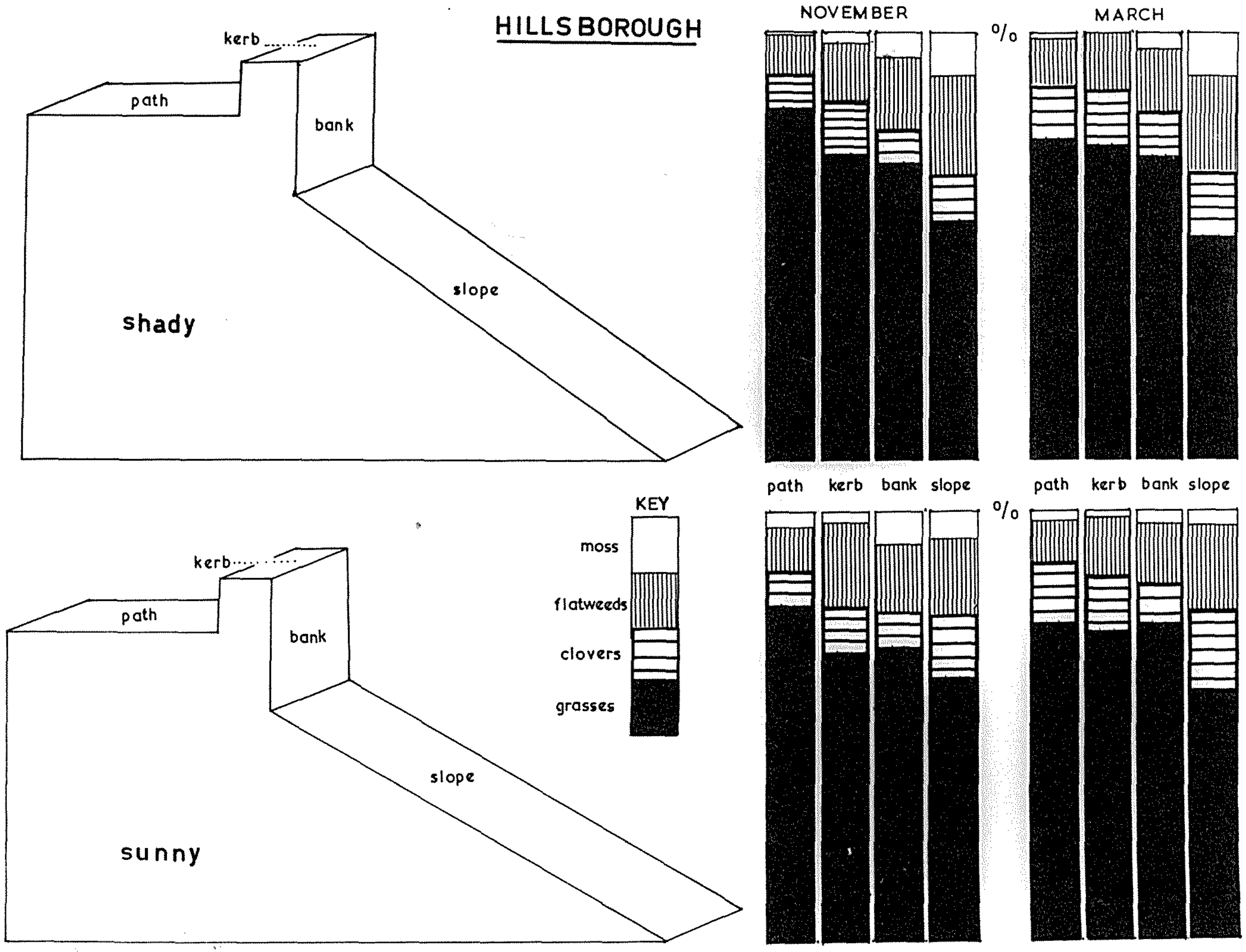


Fig. III. 3 Hillsborough. Relative Average Dimensions of Unit Slope Zones and Growth Form Patterns.

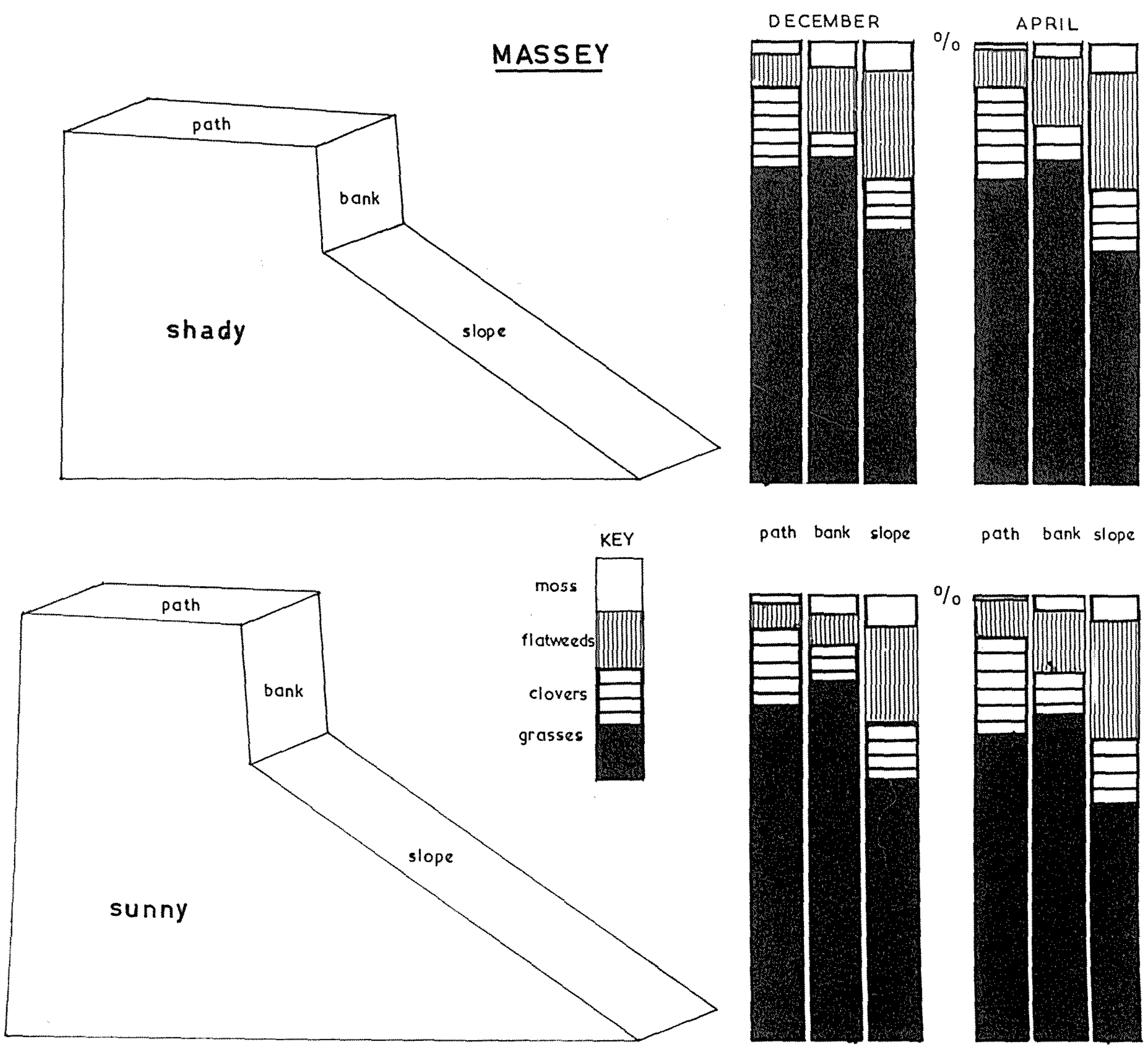


Fig. III.4 Massey. Relative Average Dimensions of Unit Slope Zones and Growth Form Patterns.

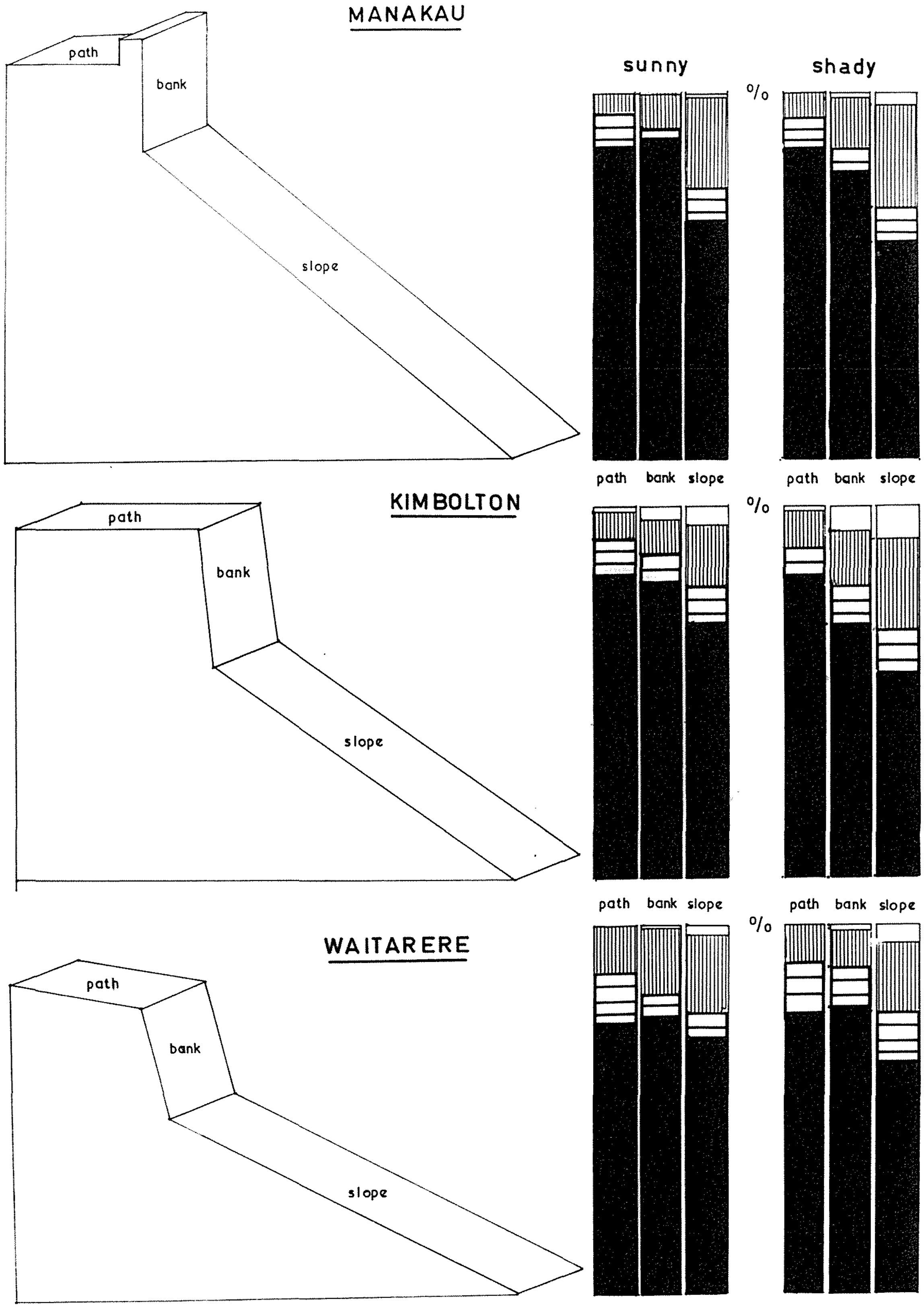


Fig.III.5 Manakau, Kimbolton, Waitarere: Relative Average Dimensions of Unit Slope Zones and Growth Form Patterns.

(b) Composition Patterns -

The zone "preferences" of the most prominent species in each transect and the significance or otherwise of these variations in relative abundance, are listed in Table III.5. This is a summary of raw and transformed data which is set out in the Appendix Tables.

Because of the skew distribution of binomial data for percentage of surface cover, transformation was necessary before analysis. The angular transformation, $p = \sin \phi$ was used from tables given by Fisher and Yates (1963). The significance of variations in abundance between zones was tested by analysis of variance in which zones represented treatments and in which there were three replications.

Summary of Table III.5:

Inspection of this table revealed broad consistencies in the behaviour of species within different transect communities. Some had a high fidelity to a particular type of habitat, e.g. perennial ryegrass, chewings fescue; other showed little evidence of any fidelity, e.g. crested dogstail and Poa pratensis; while others again were consistently inconsistent, e.g. Yorkshire fog, selfheal (Prunella vulgaris) and Lotus major (Lotus pedunculatus).

Species which appeared to flourish best on the path included perennial ryegrass, white clover (on all sites but one) and Poa annua. Sweet vernal thrived noticeably better on the path at two sites and browntop at one.

TABLE III.5 HABITAT PATTERN & SIGNIFICANCE OF MAJOR SPECIES

Major Species	Hillsborough				Massey				Waitarere		Kimbolton		Manakau	
	Nov.		March		Dec.		April							
	Sunny	Shady	Sunny	Shady	Sunny	Shady	Sunny	Shady	Sunny	Shady	Sunny	Shady	Sunny	Shady
Browntop	B.K*S*P	B*K*S*P	B.K*S*P	B*K*S*P	B*S*P	B*S*P	B*S.P	B*S.P	S.B.P	B.P*S	P*S.B	P*B.S	B.S*P	B*S*P
Perennial rye.	P*S.K*B	P*SPK.B	P*S(K)*B	P*S*B.K	P*B.S	P*B.S	P*S.B	P*S.B	P*S.B	P*S.B	P*S.B	P*S.B	P*S.B	P*S.B
Sweet vernal	S*B(K)*P	S*B.K.P	S*B.P.K	S*K.B.P	S.B.P	S.B*P	S*B.P	S.B.P	S.B.P	B.S*P	P*B.S	P*S.B	P*B.S	P*S.B
Chewings fesc.	K*B(S)*P	K*B.S*P	K*B*S.P	K*B*S.P	B.S	B	B.S	B	B*S.P	B.P=S	B*S.P	B.P.S	B*S.P	B*S.P
Yorkshire fog	B.S.K.P	B*K.S.P	B.S.P.K.	B*K(P)*S	B*S.P	B.S.P	B.S.P	B.S.P	P.S.B	B.P.S	S.B.P	B.P.S	S.B.P	B.S.P
Cr.dogstail	K.S.B.P	P.S=B.K	S.K.P.B	P.S.B.K	P.S.B	B.S.P	P.S.B	B.S.P	P.S.B	P.S.B	S.B.P	S.P.B	B.S.P	P.S.B
Cocksfoot	B*S*	B*S*	B*S(K)*	B*S*	B*S*P	B*S	B.S.P	B*S.P	B*P.S	B(S)*P	B.S	B(S)*P	B.S.P	B*S*
Notodan. spp.	K(B)*S	K(B)*S	K*B.S	K*B(S)*	B.S*	B*S	B*S*	B*S.P	B*S.P	B.S	B*S.P	B.S*P	B*S*	B*S
Ratstail	K.B.S	K.B.S	K.B*S	KB*S.P	-	-	-	-	B.S*P	B.S*P	-	-	B*S*P	B.P.S
Poa pratensis	K.B.S.P	K.B.S.P	P.S.B.K	K.B.S	S.B.P	B.P.S	S.P.B	B.P=S	-	-	-	-	-	-
Poa annua	P*S*	P*S(B)*	P*S	P*	P*S.B	P(S)*	P	P.S	-	-	-	-	-	-
Hairgrass	-	-	-	-	-	-	-	-	S.B	S	B(S)*P	B.S.P	S(B)*	S.B*P
White Clover	S.P.K.B	K.S.P.B	S.P.K.B	P.K.S.B	P*S.B	P(S)*B	P*S*B	P*S*B	P*S.B	P.S.B	P*S*B	S.P.B	P.S*B	P(S)*B
Lotus	K.S.B.P	K.S.B.P	S.B.P.K	S.P.K=B	-	-	-	-	-	S.P.B	-	B.P=S	-	B.S
Sub. clover	-	-	-	-	-	-	-	-	-	-	B.S.P	B.S*P	S	S.B
Hawkbit	S.B.K*P	S.B.K.P	S.K.B.P	K.B.S*P	S*B*P	S*B*P	S(B)*P	S.B*P	S*B.P	S.B*P	S*B.P	S*B.P	S*P.B	S.B.P
Plantain	S*P.B.K	S*P(B)*K	S.P.B*K	S.P.B*K	S.P.B	S.P.B	S.P.B	S*P.B	-	P(S)*B	-	S.P.B	-	P.B.S
Catsear	K.B.S	K.S	K.S.B	K.S	S.B	S.B	S*B	S*B	B.S.P	S.B	S.B.P	S.B.P	S.B.P	S.B.P
Selfheal	B.S.P=K	S.P.B.K	K.S.B.P	S.P.K.B	S.B.P	B.S.P	S.B.P	B.S.P	P.B.S	S.P.B	S.P.B	S.B.P	-	S.B.P
Yarrow	K.B.P.S	K(B)*(S)*P	P.S=B.K	S.B.P.K	-	-	-	-	-	-	-	-	-	-
Moss	B.S.P.K	S(B)*(K)*P	S.B.P.K	S*B*P*K	S*P.B	S.B*P	S*B.P	S.B.P	S.B.P	S.B.P	S(B)*P	S.B*P	S.B	S.B.P
Bare Ground	K*S.B.P	K.S.B.P	K*B.S*P	K(S)*B.P	B.S.P	P.B.S	P.S.B	S.P.B	P.S.B	P.S.B	S.P.B	P.B=S	B.S.P	B(S)*P
Cover Rep.	P*S.B*K	P*B*S.K	P*B.S*K	B.P*S.K	P*B.S	P.S.B	B.P.S	S.B.P	P.S.B	P*S.B	S.P.B	P=S.B	P.B.S	P.B*S
Total species	28	28	26	27	26	26	26	27	28	23	18	24	20	28

Habitats: P = Path, K = Kerb, B = Bank, S = Slope.

Species showing a significantly higher abundance on the slope included the weeds; hawkbit, plantain, catsear (*Hypochaeris radicata*) and moss. Minor species such as selfheal, mouse-eared chickweed (*Cerastium glomeratum*), scarlet pimpernel (*Anagallis arvensis*), dandelion (*Taraxacum officinale*), Australian linseed (*Linum marginale*), creeping speedwell (*Veronica serpyllifolia*), suckling clover (*Trifolium dubium*), and hawksbeard (*Crepis capillaris*) were also hit more frequently in this community.

The bank and kerb habitats were somewhat similar in composition, though noticeably different in structure. Browntop generally dominated this area but a group of species which seemed to do better here also, were; chewings fescue, Notodanthonias, cocksfoot, and ratstail. Where hairgrass (*Vulpia bromoides*) occurred it also "favoured" this habitat.

Little significant evidence of consistent patterns in pasture structure was found. The path community tended to be a little longer than the others, which may have compensated for the lack of a bottom layer of species in many cases. With ryegrass dominance, either white clover or Poa annua tended to fill in the gaps, while where vernal or browntop were dominant, a shorter, denser mat was formed. The slope community was generally the shortest, but species, in particular flatweeds and moss, left little ground exposed. Dense mat-like, trailing stolons from browntop often clothed the bank and chewings fescue, where it thrived, formed thick tufts.

In the following figures the distribution's of prominent species in each transect are shown and they illustrate a wide range of pattern types and intensities. In some species there are fundamental differences in the distribution patterns at various sites.

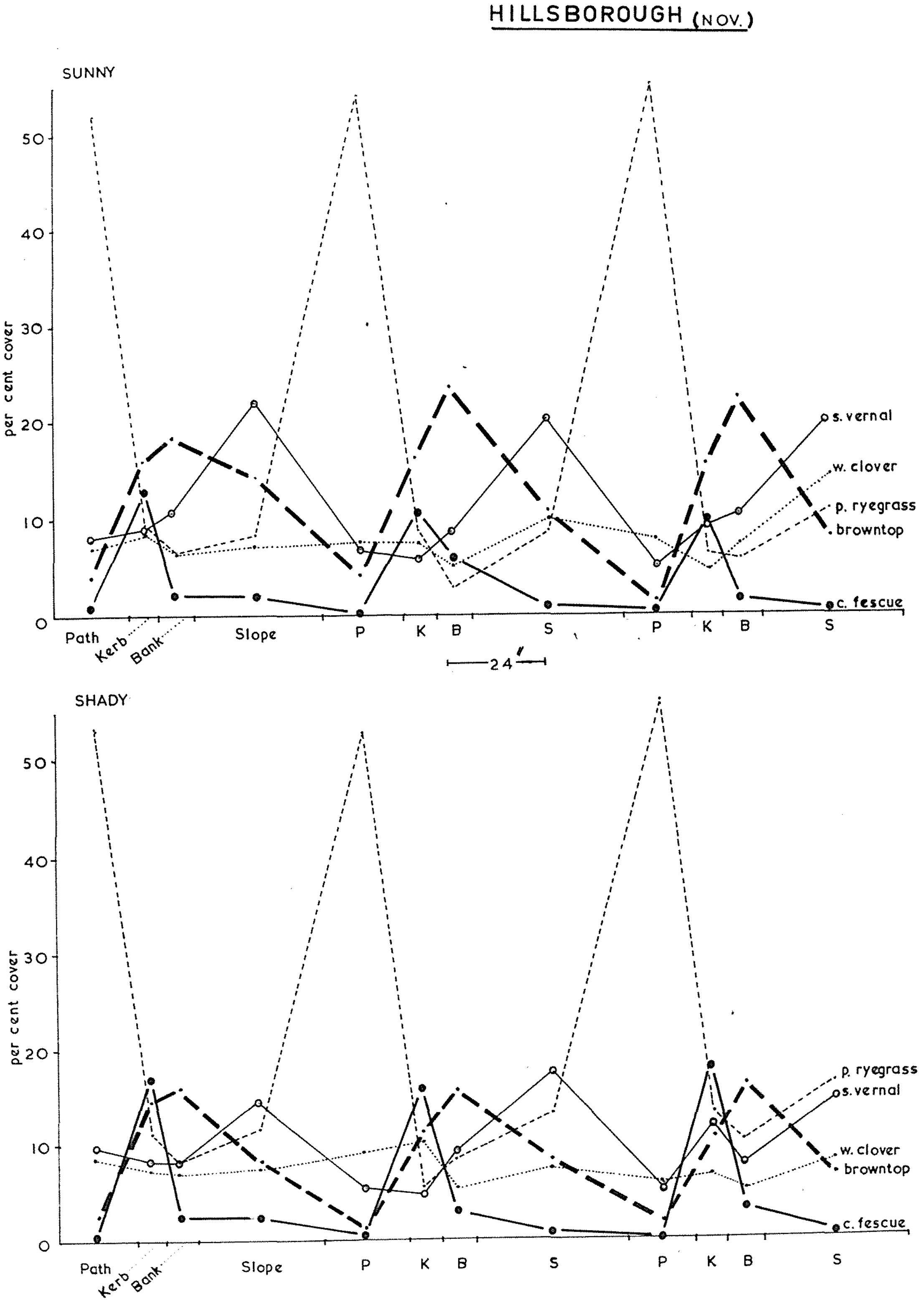


Fig. III.6 Patterns of Relative Abundance in Relation to Slope Zones.

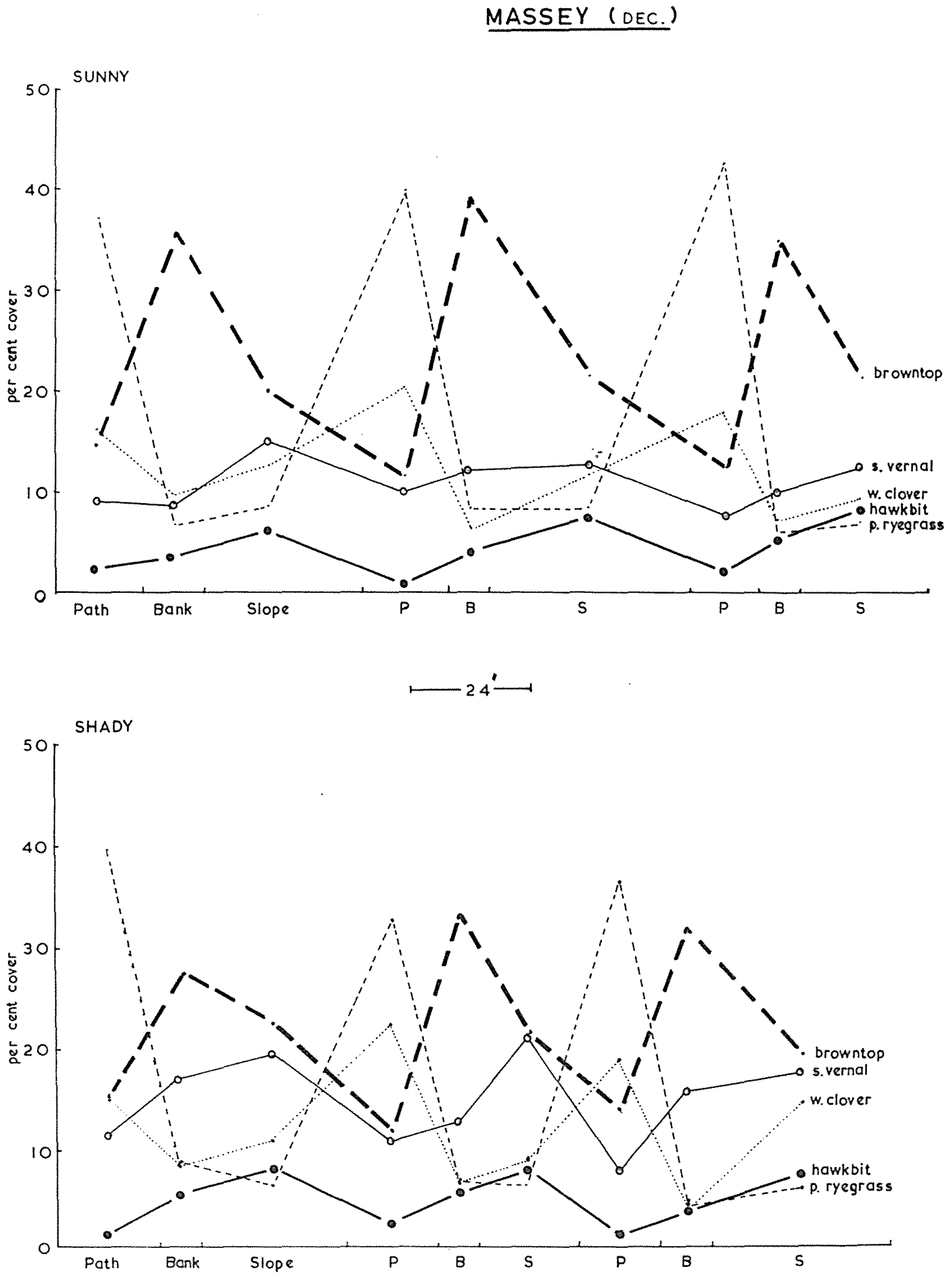


Fig. III.7 Patterns of Relative Abundance in Relation to Slope Zones.

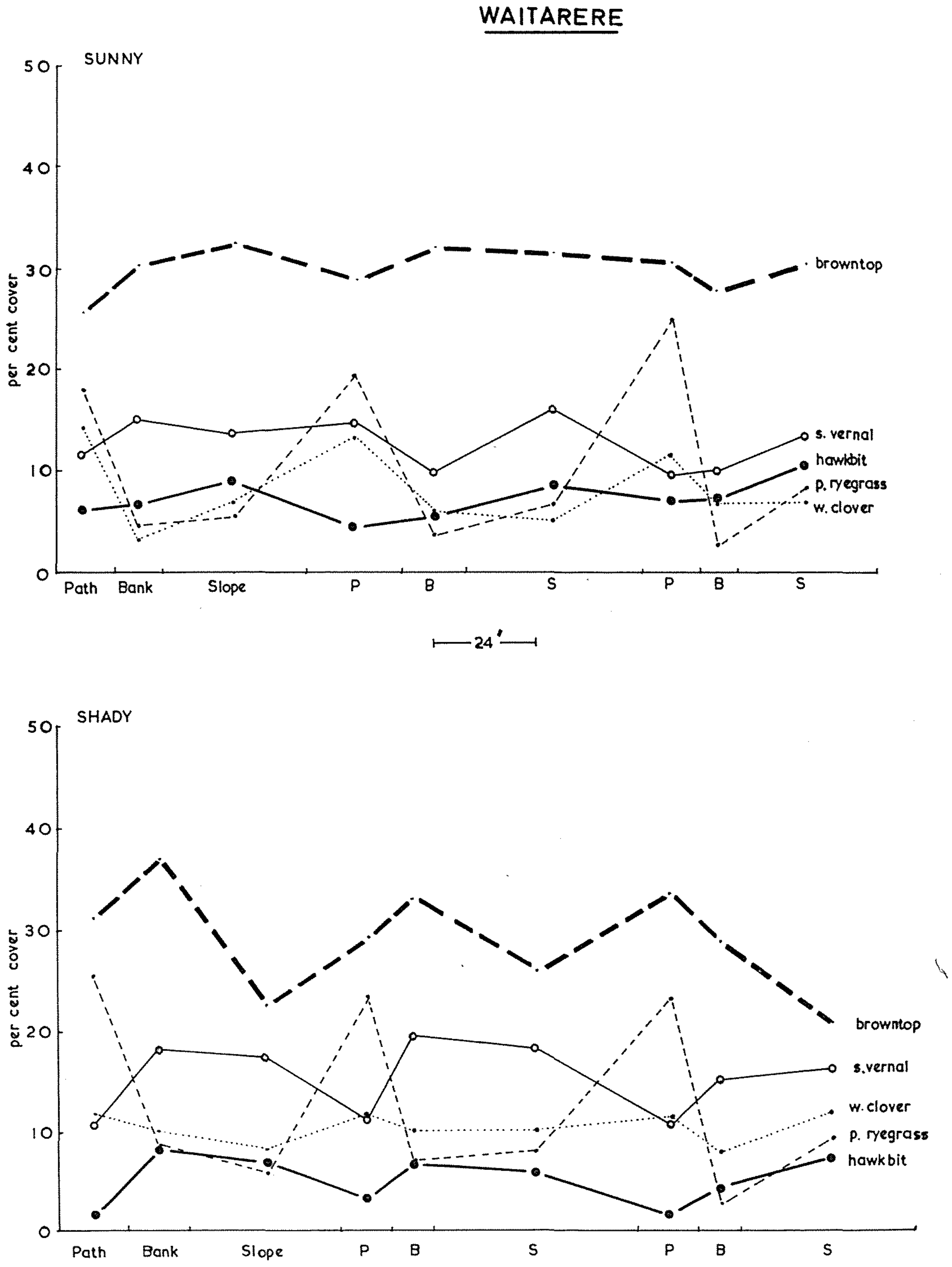


Fig. III.8 Pattern of Relative Abundance in Relation to Slope Zones.

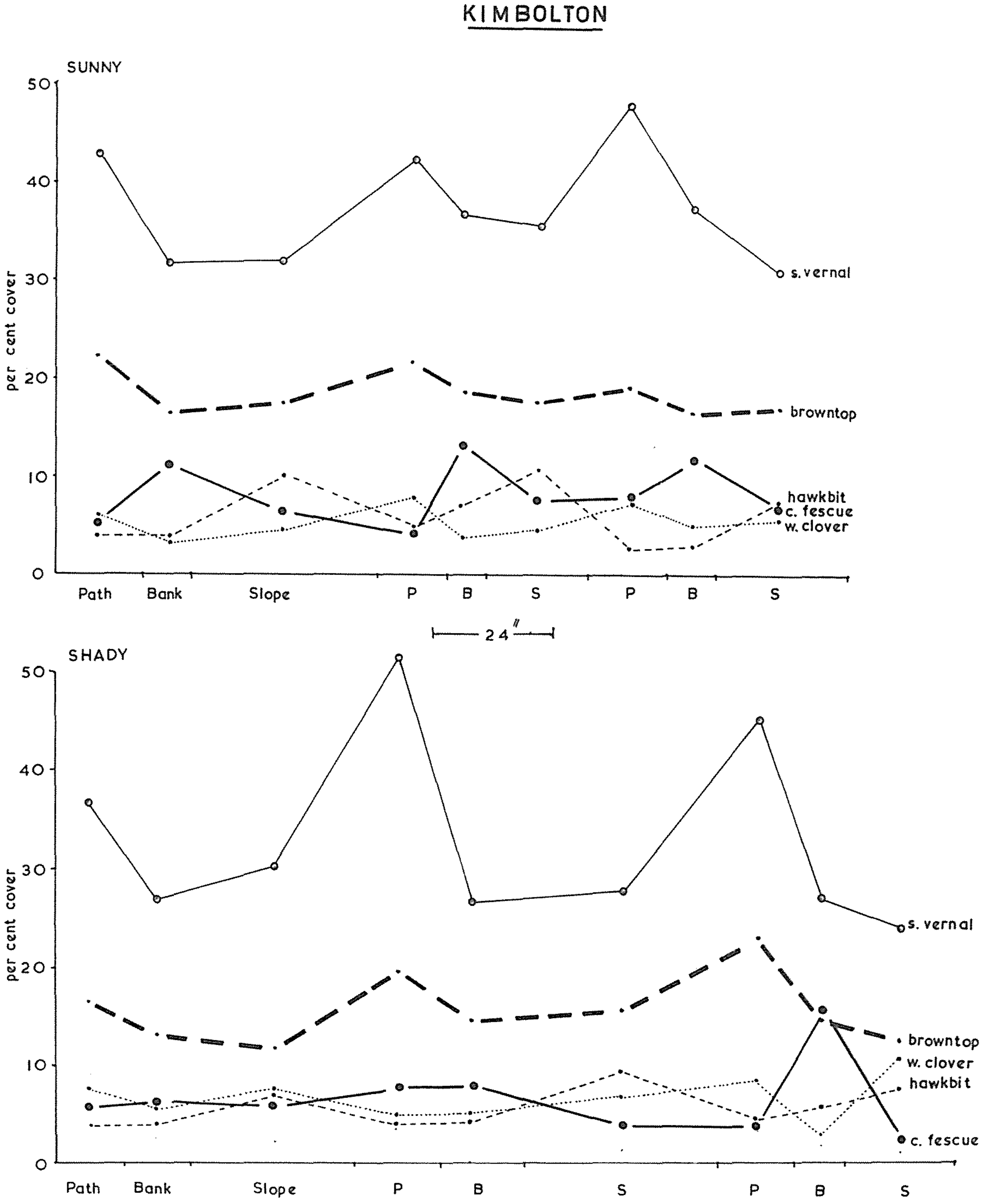


Fig. III.9 Patterns of Relative Abundance in Relation to Slope Zones.

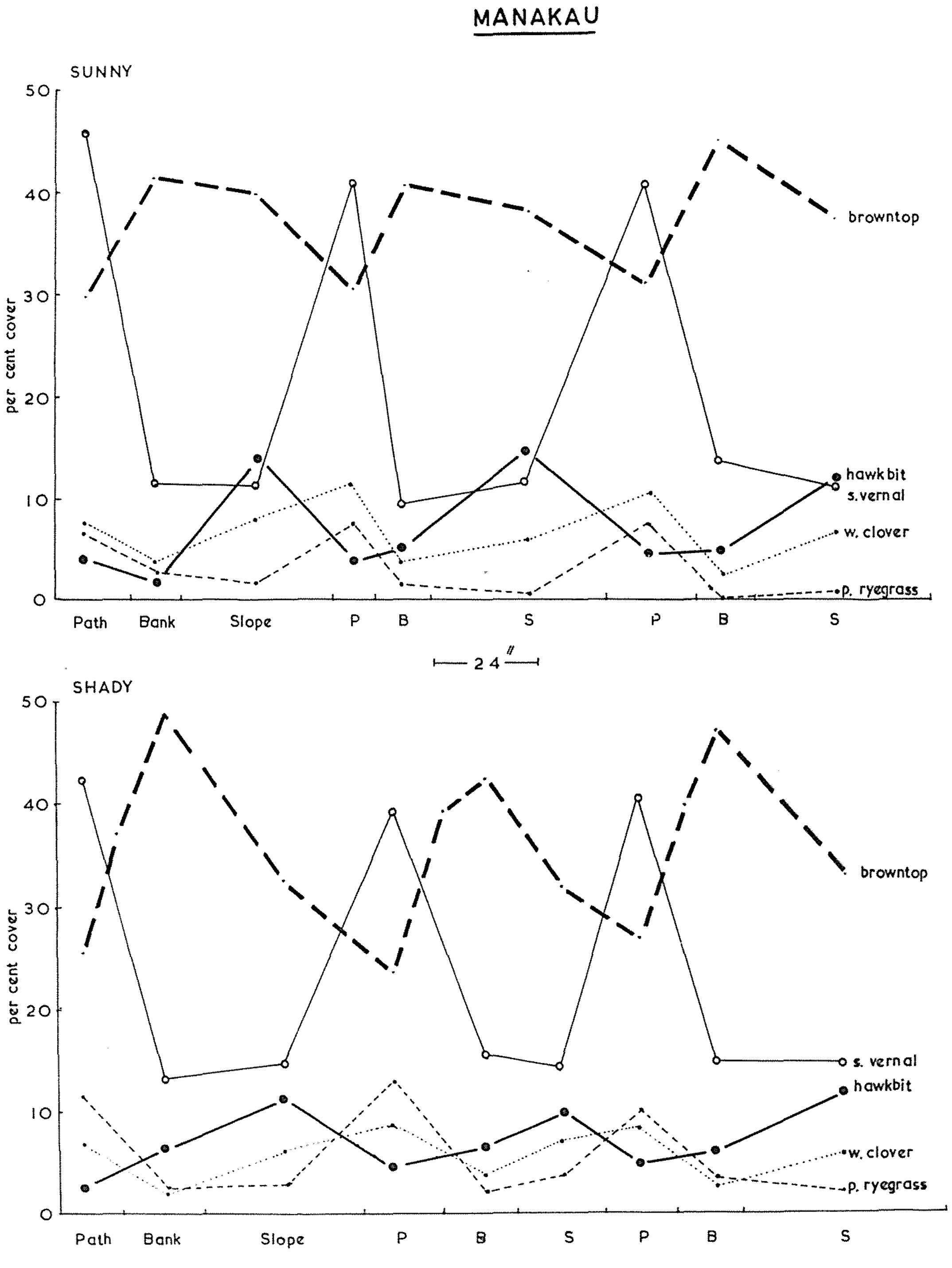


Fig. III. 10 Patterns of Relative Abundance in Relation to Slope Zones.

Summary of Figs.III.6-10.

In general, most species showed a marked "preference for" a particular type of slope zone and often a marked intolerance of others. These patterns were often consistent not only within transects, but between aspects and between sites, e.g. the comparative abundance of perennial ryegrass on the path.

Alternatively the type of pattern shown by a species sometimes varied between sites although it was invariably similar between aspects at a particular site. For example, sweet vernal showed a "preference for" the slope at Hillsborough and for the path at Kimbolton and Manakau. Similarly white clover, evenly distributed at Hillsborough, flourished on the path at Massey. Browntop also showed a variable behaviour. At Hillsborough, Massey and Manakau it tended to form a thick cover over the bank, but at Waitarere it was more abundant on the path.

The patterns of chewings fescue and hawkbit, the only other two species illustrated, were highly consistent. Chewings fescue tended to form a fringe along the outer edge of the path extending part way down the bank. Elsewhere its occurrence was spasmodic. Hawkbit was the most prevalent flatweed on all but one site, and showed a strong "preference for" the wide slope community. It's occurrence in other zones was relatively low.

The main features of the pattern at each site in summary -

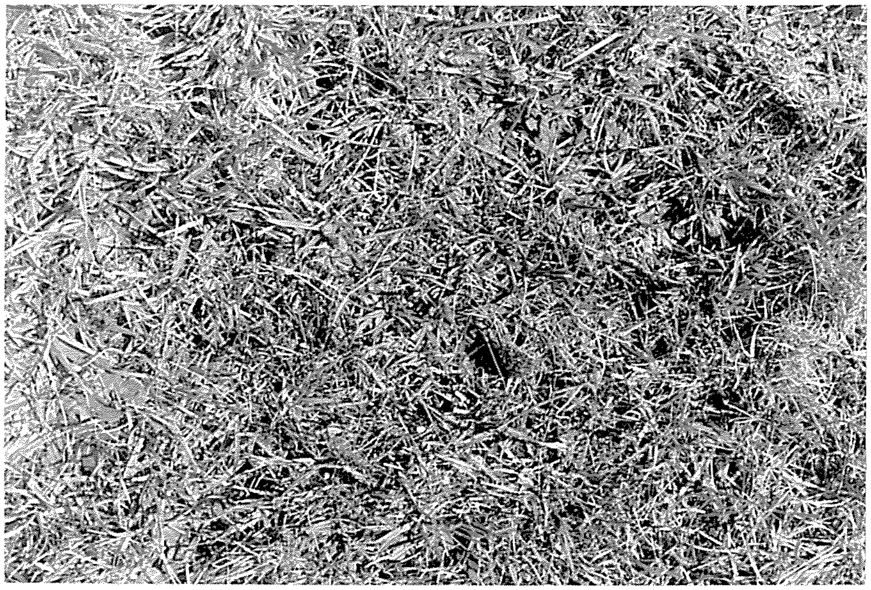
(a) Hillsborough. The dominance of perennial ryegrass on the path is striking. Browntop, sweet vernal and chewings fescue consistently showed a greater abundance on the bank, slope and kerb respectively, while white clover was evenly distributed throughout.

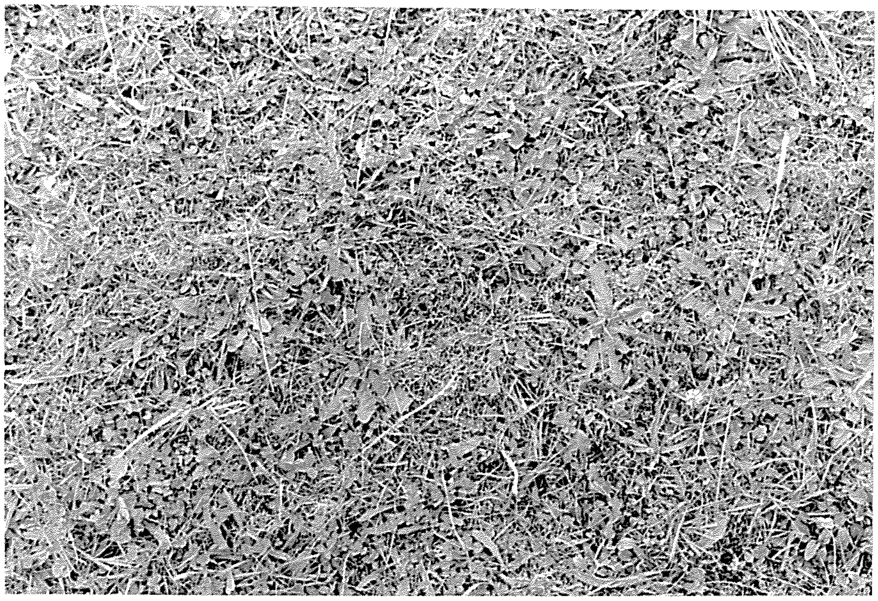
(b) Massey. Perennial ryegrass and white clover thrived on the path, hawkbit and sweet vernal on the slope while browntop dominated the bank.

(c) Waitarere. All zones were dominated by browntop on both aspects. Perennial ryegrass, and to a lesser degree white clover, "favoured" the path once more. The patterns of sweet vernal and hawkbit were less distinct, particularly on the sunny face, but in general they had a high occurrence on slope and bank.

(d) Kimbolton. There was a clear cut dominance of sweet vernal on all zones, with marked "preference" for the path. Browntop and perennial ryegrass had similar types of distribution. Hawkbit was more abundant on the slope and chewings fescue on the bank.

(e) Manakau. Browntop and sweet vernal were co-dominants here, the former on the bank and the latter on the path. Hawkbit again was most abundant on the slope and perennial ryegrass and white clover on the path.

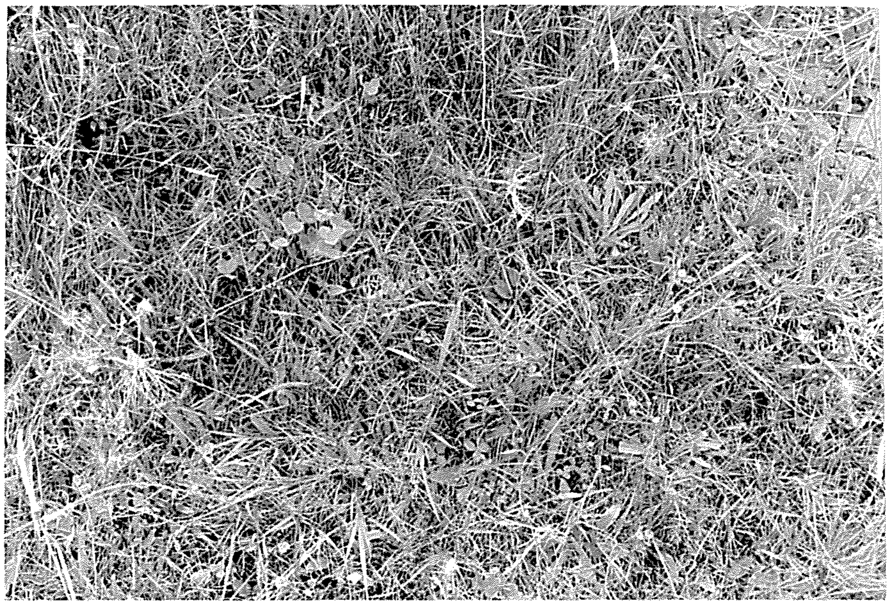




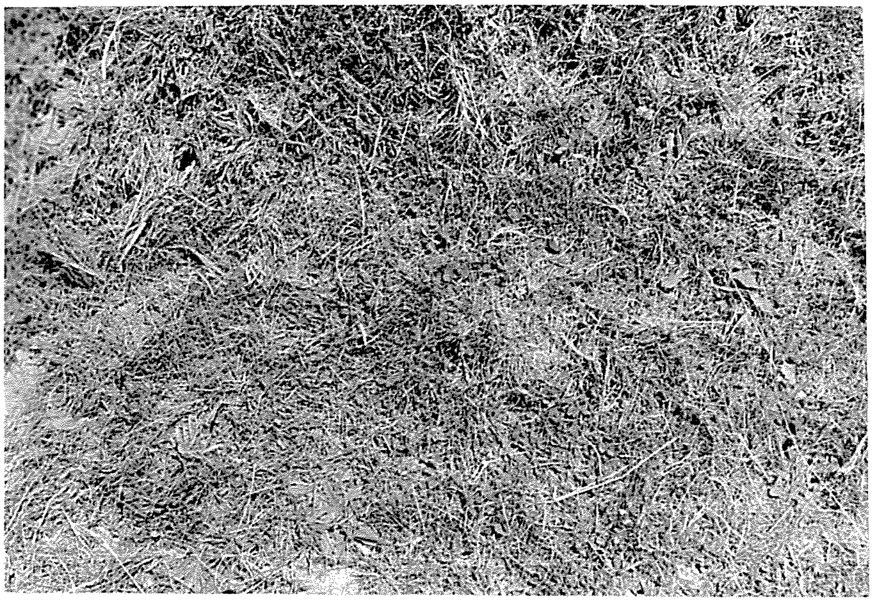
Typical Apperance of Path (upper) and Slope (lower)

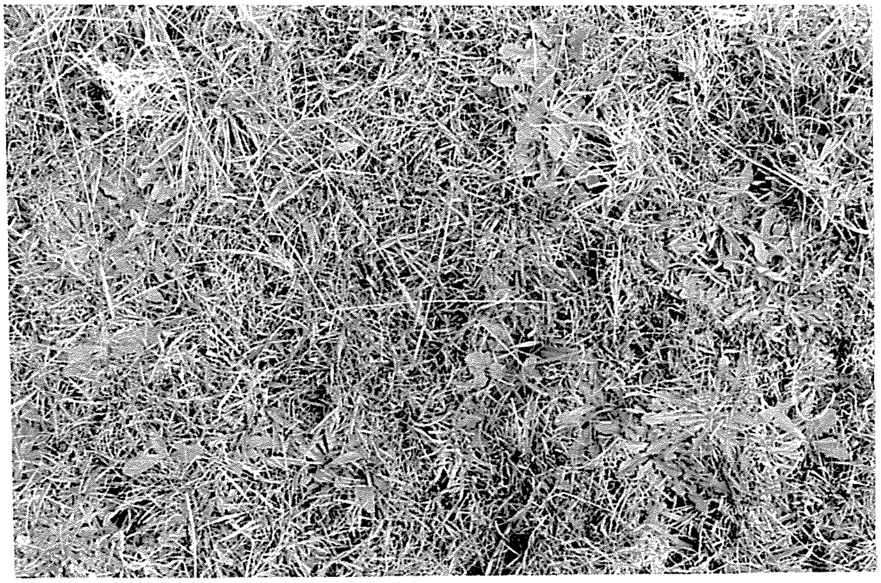
Microcommunities on Transect Sites

(c) Waitarere



(d) Kimbolton





(e) Manakau

E. DISCUSSION ON PATTERN

The distributions of species illustrated a variety of patterns reflecting a variety of causes. Kershaw (1963) has suggested three general classes of pattern: (1) morphological and (2) sociological type patterns which occur on relatively small scales within essentially uniform habitats and (3) environmental type pattern which is a reflection of a variable habitat. Basing arguement on studies of changing scales of pattern during the development of communities, Greig-Smith (1952) and Kershaw (1959) suggested that morphological and sociological patterns rise progressively to a maximum scale before gradually fading out as a community nears maturity. Only pattern of environmental origin is likely to be significant in a diverse and well-established mature community.

On the other hand Watt (1947) considers that in many communities there is a persistent species mosaic which is maintained by the interaction in space and time of dynamically related "patches". These "patches" apparently represent various development phases of the species and are caused by changes in the competitive balance over time or as a result of changes in habitat conditions.

There were no indications of any mosaic patterns on the sites sampled in this project. Small scale pattern, detectable by observation rather than from the data, was represented occasionally by relatively dense patches of white clover, tufts of chewings fescue and small mats of browntop and Y.fog. However this was associated with random phenomena such as the occurrance of stock residue or spots where the soil had previously been bared by a sliding hoof. Rather than showing small scale mosaic patterns, pastures were well assorted, even where there was a high degree of local dominance by one species.

On these basically diverse communities was superimposed an environmental pattern, manifest as consistent variations in composition corresponding to major changes in slope. Zonations in the pasture were on some sites obvious, even from casual observation, particularly where growth form patterns (see Figs. III.1-3) and pasture height or density differences accompanied composition patterns. However where pattern was less intense or there was a general similarity in pasture appearance throughout, unbiased sampling was necessary to either detect pattern or confirm that it was in fact present.

Raw data in the form of hits on each species in each quadrat revealed that in all transects, many if not the majority of species showed regular variations in abundance corresponding to changing slope. For the major species progressive variations were often noticeable from quadrat to quadrat, but for most, pattern was revealed only when relative abundance was compared in groups of quadrats. Transects were subdivided into three or four replicated zones for this purpose, according to variations in slope rather than composition. On the whole, the correspondence between physiographic and vegetation zones was, in these short pastures, reasonably good.

The types of pattern in relation to microtopography (as shown in Figs.III.4-8) are similar to the distributions of three species of Ranunculus illustrated by Harper and Sagar (1953). These diagrams for the major species form just a sample of the wide range of patterns found.

Some distributions are nearly uniform over all zones, e.g. white clover at Hillsborough, while at the other extreme are those which show a high degree of fidelity to one particular zone, e.g. browntop and perennial ryegrass at Massey. In between are the more common cases where a species shows a similar abundance in two of the zones and a significantly lower or higher abundance in the other, e.g. sweet vernal at Kimbolton and Manakau. The most common type of pattern however is the distribution in which is shown a consistent zonal "order of preference". This is characteristic of the majority of species on all sites (see Table III.5). It should be realised though that for some species this "order of preference" may be reversible between sites.

The intensity of pattern for any particular species depends on both overall abundance and fluctuations along the transect. Pattern is obviously harder to detect in minor species, but as abundance increases, variability tends to become more marked. Qualitative differences were common for minor species (thus giving them some indicator value) but became increasingly uncommon as overall abundance rose. For the major species, qualitative differences between any of the zones was an exception. In order to reach statistical significance for pattern, there needed to be a sufficient intensity of sampling, a minimum average difference in relative abundance between zones and also a high degree of consistency among replications. This was the main reason for using relative measures of abundance and for deliberately choosing sites and locating transects where uniformity was high.

The distribution pattern of each species was determined by its abundance and by its ecological behaviour in relation to both general site conditions and to the other species present. Comparisons between sites illustrate how the niche which a species fills within a community can change radically with physical and biotic conditions. The behaviour of sweet vernal provides a good example. At the Massey and Waitarere sites, sweet vernal shows a "preference" for the slope zone, although variations do not generally reach a significant level. At

Hillsborough it dominates this zone while at Manakau it dominates the path. A "preference for" the path is shown at Kimbolton as well, but here it is the dominant species throughout. Similarly browntop changes from a "bank-preferring" species on most sites, to a "path-preferring" species at Kimbolton. In contrast to these examples, perennial ryegrass, hawkbit and chewings fescue maintain a consistent form of distribution over the whole range even though varying in intensity.

It may appear, that for a particular species, the intensity of pattern is influenced by the general favourability of site conditions. Except perhaps for white clover however, there did not seem to be a falling off in pattern intensity as site conditions improved (and there was therefore an increase in overall abundance). In perennial ryegrass for instance, the most intense pattern was found at Hillsborough where this species dominated the pasture. On the whole it appeared that increasingly favourable site conditions raised abundance in all zones so that quantitative differences and pattern intensity tended to be maintained.

Every species filled a unique role within the pasture community, determined by its overall abundance and distribution. Those species with similar ecological behaviour occurred together to form microcommunities generally distinct in composition and often distinct in structure. Differences in the appearance of microcommunities occupying adjacent slope zones are shown in the figures following this chapter.

The "boundaries" between microcommunity types ranged from hardly perceptible to abrupt. In general, the sharpness of the transition depended on the abruptness of changes in slope. Between the path and the bank for example where there occurred up to 90° change in slope, the change in composition was typically sharp. Transitions between bank to slope and slope to path were invariably well defined. Where the pasture was long, not only transitions were blurred but even differences between microcommunities.

In summarising this discussion, it has been noted that pastures on a diverse range of physical sites showed close similarity in types and intensities of pattern. Each pasture was a complex assortment of species, but the regular fluctuations of many in relation to surface configuration produced a zonation pattern within each transect. Distinct microcommunities were produced by the coincident distribution patterns of ecologically-related species. Compositional and structural differences were caused by a combination of quantitative variation in major species and qualitative variation in minor species.

CHAPTER IV. HABITAT ANALYSES:

A. INTRODUCTION

In the previous chapter it was concluded that the characteristic distribution patterns shown by species, expressed consistent variation within the above and below ground environments. Attempts to confirm this hypothesis are described in this chapter.

Slope was recognised as the master factor, being directly or indirectly responsible for all other habitat factors which influenced the pasture community in a differential manner. Under the direction of gravity, there is a constant tendency for material to move. Large and small soil particles gravitate slowly down the sloping surface or are carried swiftly downwards by running water. Within the soil profile too, free water percolates downwards carrying dissolved plant nutrients. This continual transfer of moisture and fertility from the steep to the less steep is bound to cause significant variation in the soil environment.

Furthermore, stock may preferentially graze the vigorous community exploiting the better conditions. They will in any case, tend to use the more level areas as paths, or platforms on which to rest or to stand while grazing the sidlings. Since they will spend more time on these areas, treading effects will be higher and the deposition of excreta heavier.

To determine what were the effects of slope variation on certain soil factors and animal behaviour was the purpose of trials carried out on a two acre site at the Massey University terrace farm during the summer and autumn of 1966.

Three plots (A, B, C) were marked out on the sunny (L) and shady (R) aspects, two of which contained the permanent transects (RB, LC). Most of

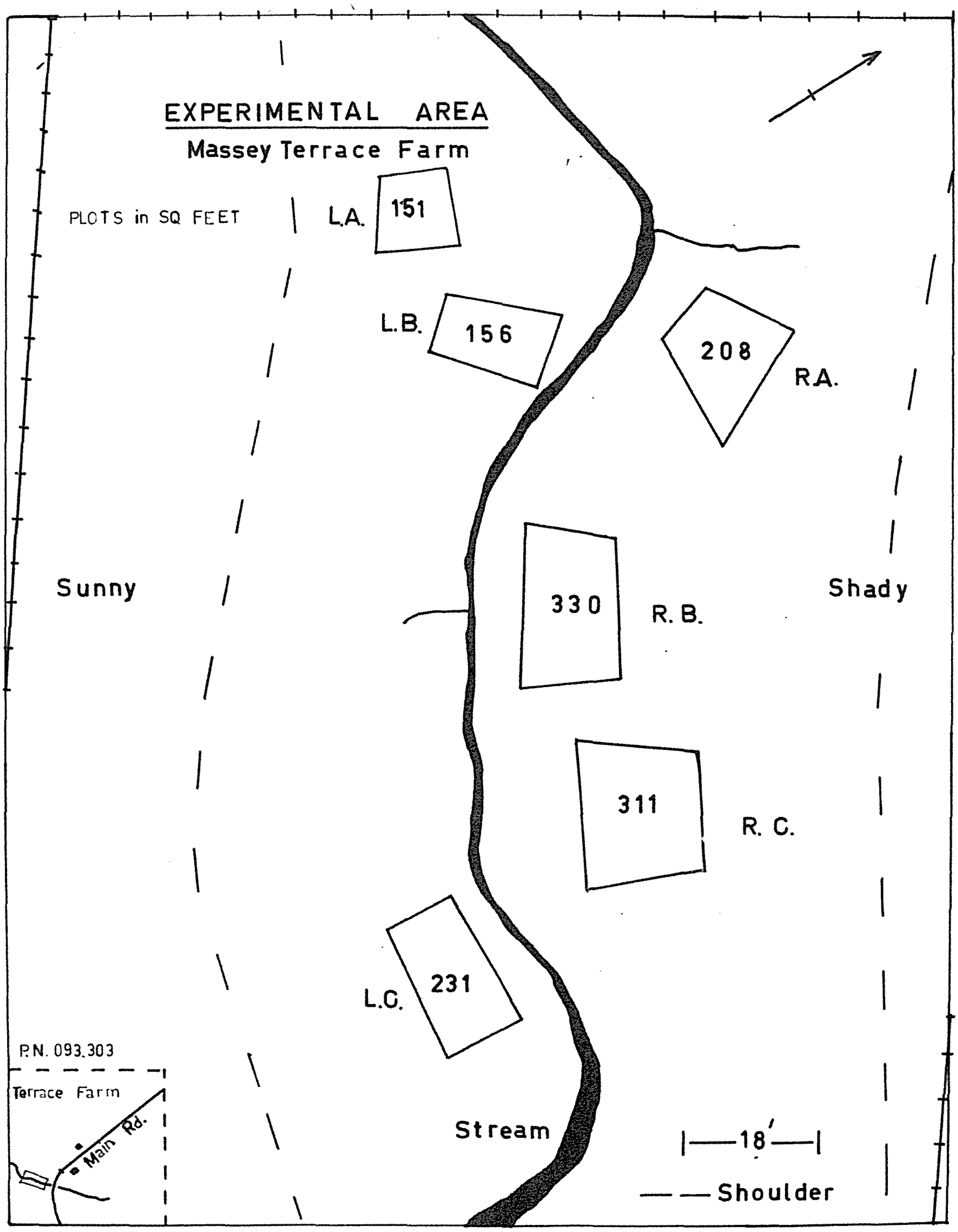


Fig. IV. 1 Location of Experimental Area and

Plot Positions.

the sampling was spread over the four remaining plots, which appeared from inspection to carry similar types of pasture.

The location of the site and plots is shown in Fig.IV.1 and photographs of the area in Fig.IV.2. Plot dimensions appear in Appendix Table 18.

Fig.IV.2 Massey Site. Sunny (left) and Shady (right) Aspects.

B. ROOT PROFILES

Once it was obvious that significant variation existed in pasture composition, it was thought worthwile to look for corresponding variation in the bulk and disposition of root systems.

Two root profiles were taken from slope and path microcommunities during January 1966. A nailboard measuring 36" x 24" x 4" was constructed on the lines of that described by Schuster and Wasser (1964). This was jacked into an exposed soil profile, cut away and carefully trimmed. After soaking in running water for two days, the soil was hosed away, leaving a root profile outlined on the retaining wiremesh. (See Figs. IV.3 and IV.4).

The roots were separated from the foliage and were removed in 2" bands parallel to the ground surface. The dry weight of these bands were measured and results appear in Table. IV.1.

TABLE IV.1 DRY WEIGHT ANALYSES OF ROOT PROFILES

Depth	Sunny Face				Shady Face			
	Slope		Path		Slope		Path	
	gms	%	gms	%	gms	%	gms	%
0-4"	43.8	82.9	42.9	73.2	42.3	81.0	40.1	69.3
4-8"	4.9	9.3	10.6	18.1	6.6	12.5	12.9	22.2
8-12"	2.3	4.3	2.5	4.2	1.1	2.2	2.3	4.0
12-24"	1.7	3.2	2.2	3.8	1.6	3.0	2.0	3.4
24-36"	0.3	0.5	0.4	0.7	0.7	1.3	0.6	1.1
TOTALS	53.0	100.0	58.6	100.0	52.3	100.0	57.9	100.0

To give realistic comparisons, values for the bottom 12" of the slope profiles were found by extrapolating from the amount present in the top 24".

There was nearly a 5% difference in root bulk in favour of the path communities, but the dispostion of roots was similar in both. In all cases over 90% of the bulk lay within the top 8". However it was noticeable that under the slope communities an average of 82% lay within the top 4" in comparison to 71% for the path communities. This suggested that the most favourable root environment extended a little deeper under the path. The maximum extension of root systems appeared to be similar for both microcommunities. (See Figs. IV.3, IV.4).

C. SOIL VARIATION

Studies were made of variation in the physical aspects of the soil, including moisture and structure, associated with surface configuration. Comparisons were made mainly between path vs. slope habitats and sunny vs. shady aspects.

(i) Soil Type and Description

The soil of the Massey terrace farm is classified as a Tokomaru silt loam derived from alluvium. (Soil Bureau 1954). The type profile is given as:

6-8" dark brownish-grey heavy silt loam.
24" pale brownish-yellow mottled clay loam,
on mottled compact sandy clay loam.

This description was compared with soil profiles revealed whilst taking root samples.

The main departure was the occurrence within the B horizon of a zone of approx. 1" diam. ironstone nodules. In places they were abundant enough to form a nearly continuous layer varying between depths of 18" - 30". This layer and the very marked mottling which occurred, is evidence of a seasonal flow of water from the terraces through the gully profile. Water logging of this soil is particularly

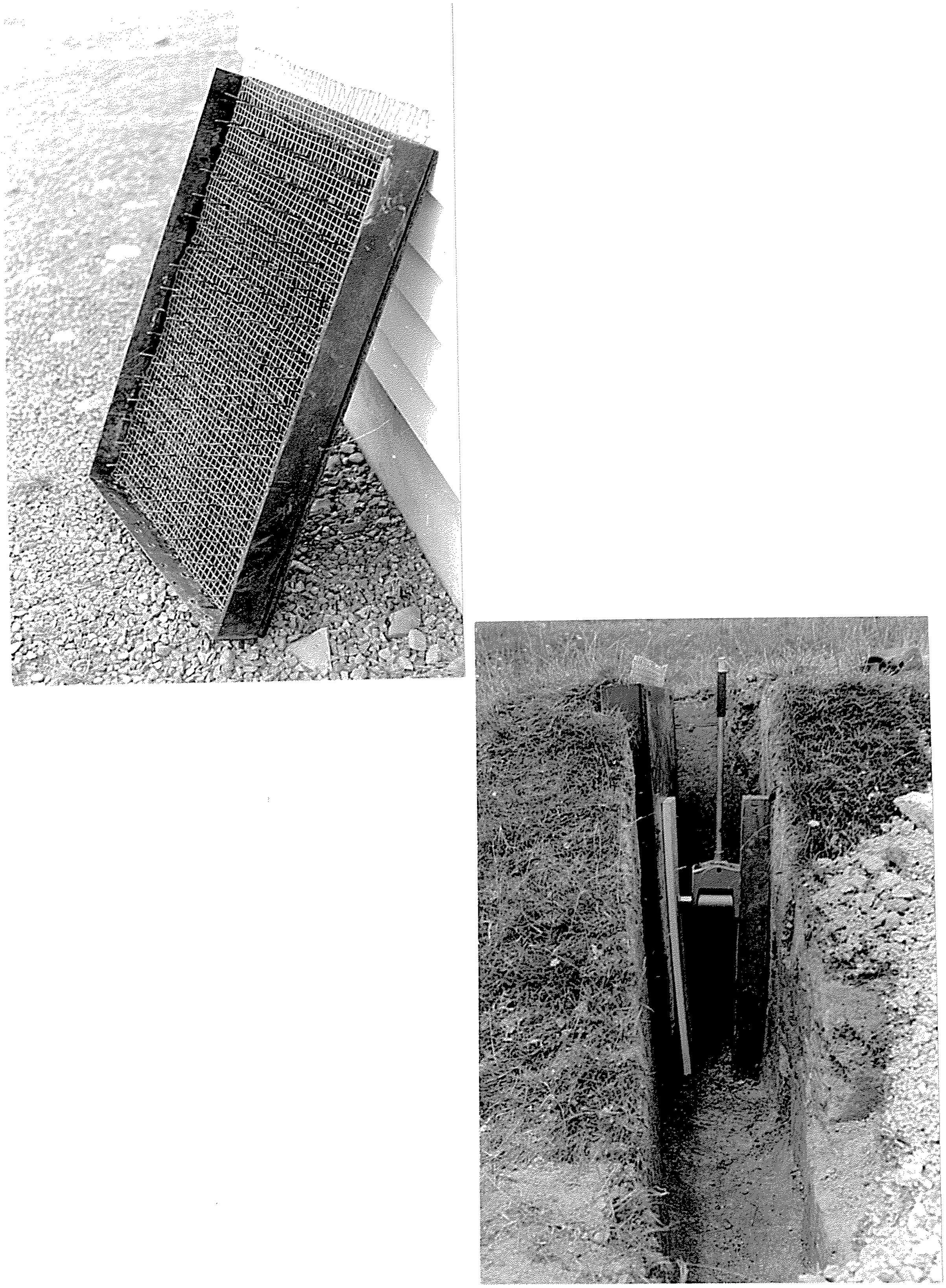


Fig.IV.3 Taking of Root Profiles with Nailboard

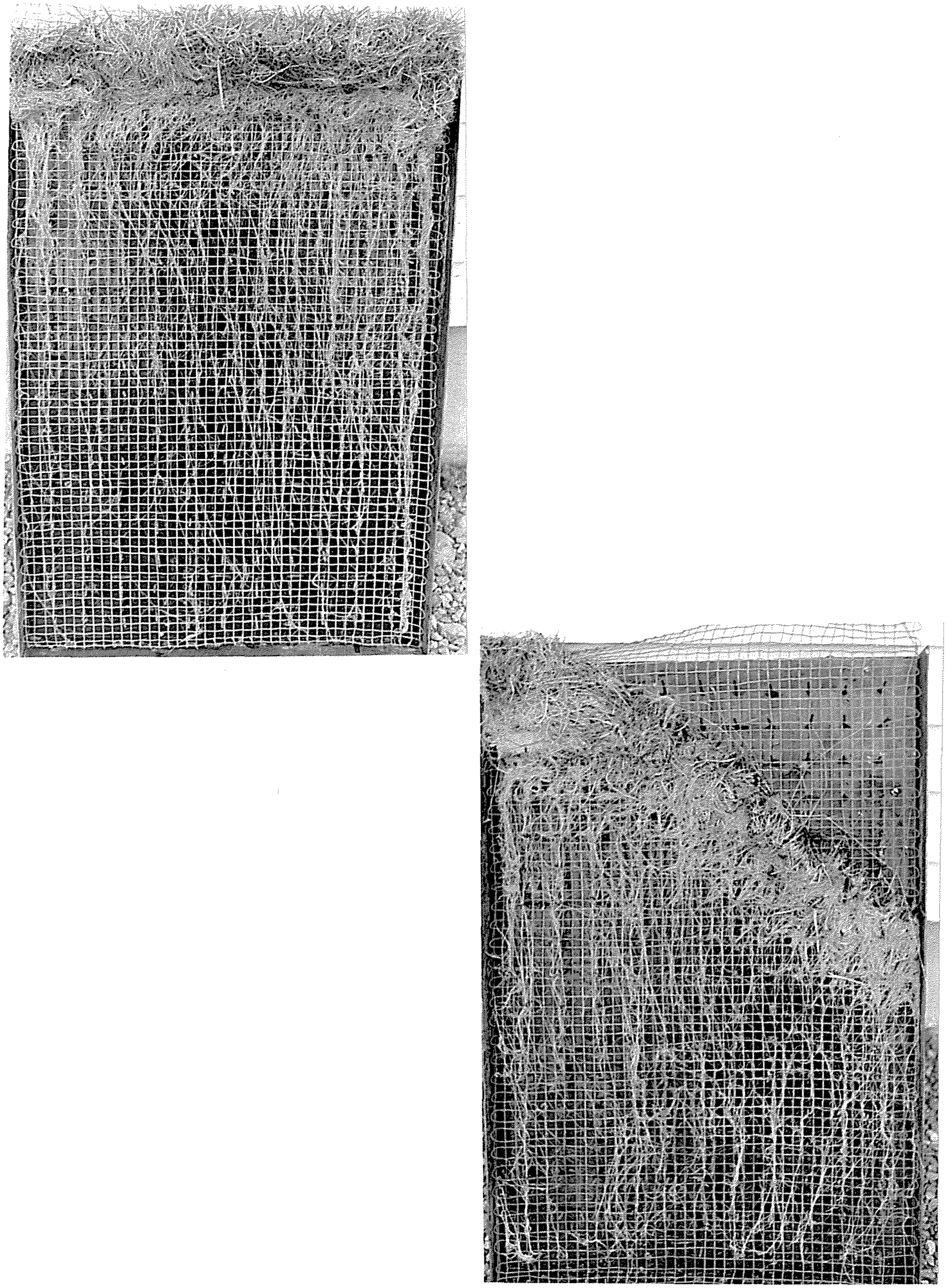


Fig. IV.4 Root Profiles Under Path (upper) and Slope (lower) Microcommunities.

noticeable during a wet winter. The soil horizons tended to mirror the configuration of the surface, so that the depth of the A horizon varied by only a few inches.

(ii) Soil Moisture

Sampling of soil moisture within the main root zone was carried out during the driest four month period of the year, on the following dates: 2.12.65, 7.1.66, 9.2.66, 13.3.66, 28.3.66. Comparisons were made between sunny and shady aspects and within these, on path and slope habitats. Core samples (2" long and 1" diam.) were assessed for percentage loss of weight after oven-drying.

First sampling - 2.12.65

The first sampling was carried out with two aims in view. Firstly, to compare moisture levels at different soil depths, and secondly, to determine variability and the number of samples needed for habitat comparisons. A total of 120 cores distributed evenly between the two habitats of the two aspects were taken @ 1 - 3"; 60 were taken @ 6 - 8" and 60 were taken @ 10 - 12".

TABLE IV.2 SOIL MOISTURE 2.12.65 ANALYSES

Depth	Source of Variation	S.S.	dF	M.S.	F	F req. & Result
1-3"	Aspect	74.7	1	74.7	12.2	** 3.9 (6.9)
	Habitat	68.6	1	68.6	11.2	** "
	Interaction	1.7	1	1.7	-	N,S. "
	Residual	709.8	116	6.1		
	TOTAL	854.8	119			
6-8"	Aspect	39.0	1	39.0	26.0	** 4.0 (7.1)
	Habitat	1.9	1	1.9	-	N.S. "
	Interaction	1.4	1	1.4	-	N.S. "
	Residual	81.8	56	1.5		
	TOTAL	124.1	59			
10-12"	Aspect	5.9	1	5.9	4.5	* 4.0 (7.1)
	Habitat	0.7	1	0.7	-	N.S. "
	Interaction	1.6	1	1.6	-	N.S. "
	Residual	71.2	56	1.3		
	TOTAL	79.4	59			

It appears from these comparisons that the shady aspect was significantly moister to a depth of at least 12". The habitat comparison showed significant advantage to the path only in the 1-3" zone. Because of this and since the great majority of roots lay within the top 4", sampling was confined to this zone in later assessments.

Using the formula $n = \frac{9V^2}{d^2}$, where V = Coefficient of Variation, d = required difference between means and n = number of samples needed, it was decided to take 20 samples per mean in subsequent comparisons.

Second Sampling 7.1.66

Sampling was carried out after heavy rain (>1"), to determine whether there was an obvious relationship between steepness of slope and water retention. Two aspects each with four classes of slope were sampled: 0-10°, 10-30°, 30-45°, 45-90°.

TABLE IV.3 SOIL MOISTURE RETENTION IN RELATION TO STEEPNESS - ANALYSIS

Source of Variation	S.S.	dF	M.S.	F	F req. & Result
Aspect	8.6	1	8.6	3.9	N.S. 4.0(7.0)
Slope	392.9	3	131.0	59.5	** 2.7(4.1)
Residual	165.4	75	2.2		
TOTAL	566.9	79			

The amount of water retained by the soil progressively declined as the slope became steeper. All differences between slope classes were significant at the 1% level.

The results from later sampling are set out in Tables IV.4 and 5.

TABLE IV.4 SOIL MOISTURE-ANALYSES

Date	Source of Variation	S.S.	dF	M.S.	F	F. req. & Result
9.2.66	Habitat	43.9	1	43.9	16.9	** 4.1 (7.3)
	Aspect	90.9	1	90.9	35.0	** "
	Interaction	10.5	1	10.5	4.0	N.S. "
	Residual	94.2	36	2.6		
	TOTAL	239.5	39			
13.3.66	Habitat	21.2	1	21.2	7.2	* 4.1 (7.3)
	Aspect	127.1	1	127.1	43.2	** "
	Interaction	1.9	1	1.9	-	N.S. "
	Residual	105.7	36	2.9		
	TOTAL	255.9	39			
28.3.66	Habitat	176.2	2	88.1	11.7	** 3.2 (5.0)
	Aspect	51.7	1	51.7	6.9	* 4.0 (7.1)
	Interaction	5.8	1	5.8	-	N.S. "
	Residual	413.5	55	7.5		
	TOTAL	647.2	59			

TABLE IV.5 PATTERN OF SOIL MOISTURE-MEANS (%s) and S.E.s.

Date	ASPECT			HABITAT			S.E.	CV.%
	Sunny vs.	Shady	SIG	Path vs.	Slope	SIG		
2.12.65								
1-3"	21.4	23.0	**	23.0	21.5	**	0.3	1.4
6-8"	19.2	20.8	**	20.2	19.9	N.S.	0.2	1.1
10-12"	18.8	19.4	*	19.2	19.0	N.S.	0.2	1.1
9.2.66	17.2	20.2	**	19.7	17.6	**	0.4	1.9
13.3.66	15.1	18.7	**	17.6	16.2	*	0.4	2.3
				Path vs.	Bank vs.	Slope	SIG.	
28.3.66	14.4	16.3	*	17.2	12.9	16.0	**	
	S.E.0.5			S.E. 0.6, d.05 (.01) 1.7 (2.3), C.V.4:0%				
				0-10°	10-30°	30-45°	45-90°	SIG.
7.1.66	28.7	29.4	N.S.	32.0	30.1	28.3	26.0	**
	S.E.0.2			S.E.0.3, d.05 (.01) 0.9(1.3), C.V.1.1%				

The seasonal trend in values for four habitats is shown in Fig.IV.5.

All habitats clearly show a progressive loss of moisture from the main root zone, but the relative positions remain unchanged. The reason for the path habitat being consistently moister than the slope may be due to either a higher input of moisture or a lower output or both. The sampling on 7.1.66 indicated that the steeper the slope the lower the water retention, due probably to the less

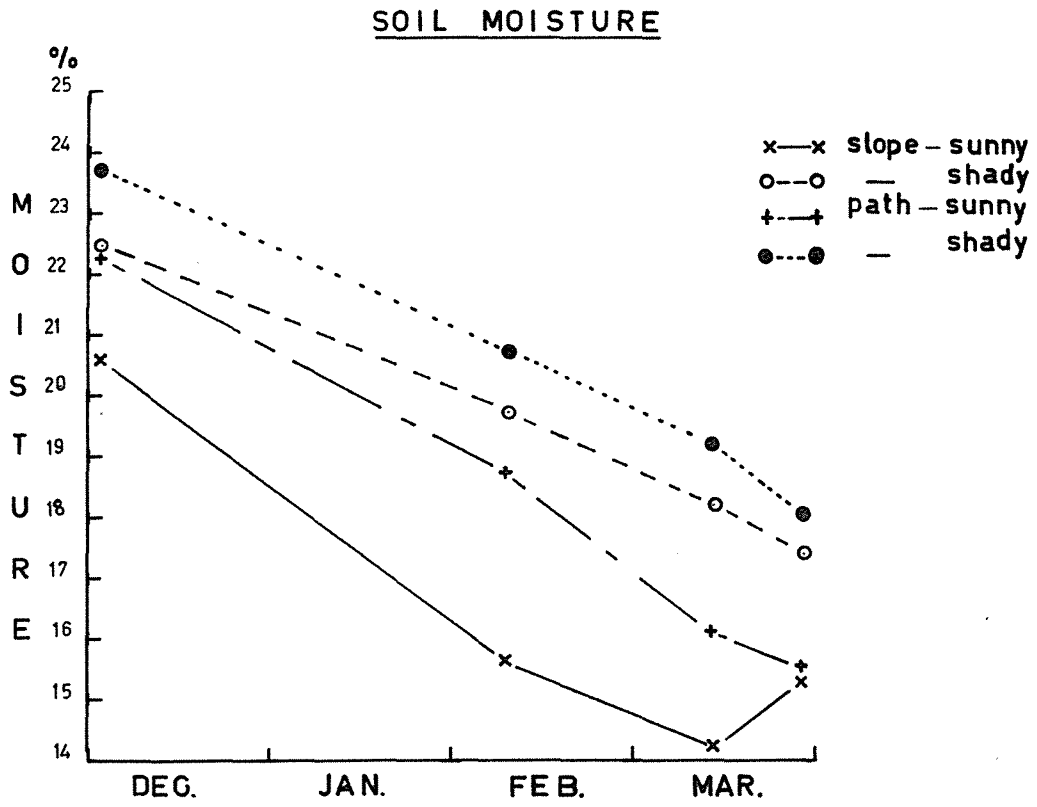


Fig. IV. 5 Habitat Values for Soil Moisture During Summer.

time available for infiltration. Path habitats probably collect a significant part of the run-off and perhaps percolation from slope habitats. No estimates of relative evapo-transpiration losses from the two types of community are available but because of the similar structure and density of the foliage and root systems, differences are not likely to be high. It seems reasonable to assume that both aspects receive a similar quantity of rain so that differences in soil moisture are attributable to differences in evapo-transpiration losses. As would be expected the sunny face is consistently drier than the shady.

Differences in the soil moisture content between path and slope habitats and shady and sunny aspects consistently reach statistical significance. However, it remains conjectural whether these differences have ecological significance. All that can be concluded is that path habitats offer slightly moister conditions than slope habitats, and that as a whole the shady face is moister than the sunny.

(iii) Soil Compaction

There was a two-fold reason for studying soil compaction. Firstly, numerous experiments have indicated that an over-compacted soil may adversely affect plant growth through interference with soil aeration and water infiltration, e.g. (Edmond 1958 b, Tanner and Mamaril 1959). Secondly, a pattern of variable soil compaction provides indirect evidence of grazing animal behaviour which may be used in conjunction with direct observations on stock.

(a) Profile Resistance -

The first investigations were made with a penetrometer kindly loaned by Mr. D.B. Edmond of Grasslands Division (D.S.I.R.). This apparatus graphically recorded changing resistance as a probe was pushed 24" into the soil. Units of resistance are convertable to pressure (as p.s.i.) so that any number of resistance profiles can be averaged to get a representative profile. In this way minor anomalies caused by the probe striking stones or worm tunnels etc., can be covered over.

Representative profiles for the four habitats are drawn on Fig. IV.6. Each comprises over a dozen trials distributed systematically over the areas. All resistance profiles from each habitat were traced on to a common graph and the composite profile illustrated, was obtained by the averaging of these. Profiles were taken when the soil had recently been moistened but was below field capacity, so that differences in resistance would be caused by variations compaction rather than in soil moisture.

The graph interpretation is as follows. All habitats clearly show zones of increasing resistance which represent significant changes within the profile. The first zone lying between 0-10" corresponds to the A horizon and the second zone to the B horizon. At variable depths within the latter, the nodular layer was hit and resistance rose to the maximum able to be recorded.

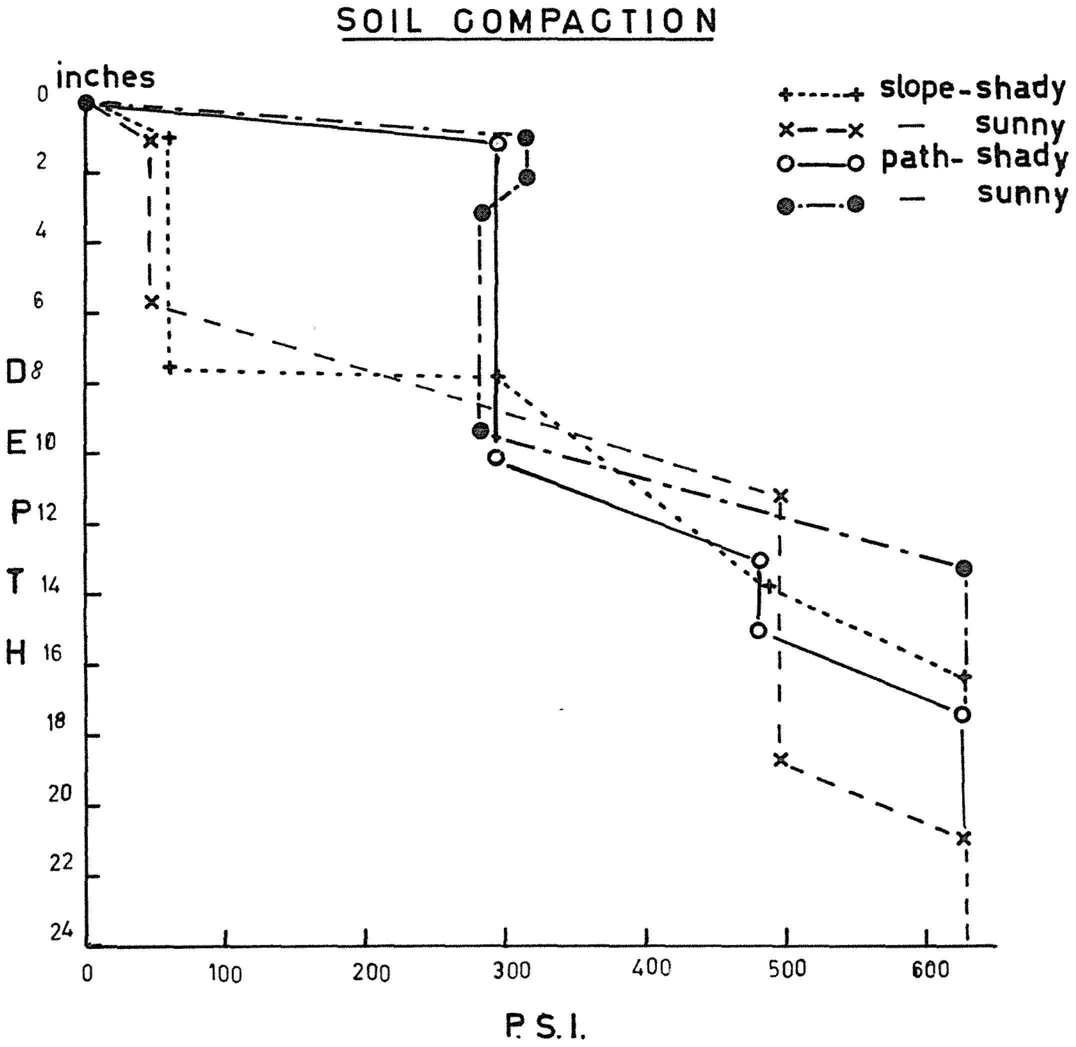


Fig. IV.6 Habitat Profiles for Soil Resistance

There was a striking difference in the resistance of the A horizon between path and slope. The divergence occurred between 0-2" and was apparently maintained down to the B horizon at 8-10". Below this there was no clear or consistent pattern of difference between habitats.

Other studies of treading effects on physical characteristics of soil (e.g. Bates 1935, Alderfer and Robinson 1947, Edmond 1958 a, 1964, Tanner and Mamaril 1959, Gradwell 1960) have indicated that heavy treading causes a narrow zone of compaction or lower non-capillary porosity near the soil surface. This is particularly so on heavier-textured soils with a high moisture content. However, below the top few inches treading appears to have no effect on soil structure.

A substantial difference in resistance between path and slope within the top 2" was indicated in this trial, but the apparent maintenance of this difference is more likely to be due to "less-than-efficient" operation of the apparatus on uneven ground, than to any real effect. Increases in resistance were indicated in an obvious way but in these conditions the apparatus was less sensitive to zones of lower resitance.

Changes in profile penetrability of a trodden soil were noted by Keen and Cashen (1932). Resistance increased with animal traffic and greatest compaction was found to occur at 3.5 cm. (approx. $1\frac{1}{2}$").

(b) <u>Surface Resistance</u> -

Depending on the moisture content and compaction, a soil surface will offer a variable resistance to a probe. Variation patterns in resistance were recorded on two occasions during the summer.

A pressure-indicating probe was used to which a range of plugs (from 0.1 to 1.0 in.^{2}) could be fitted according to the conditions. Gauge units were calibrated against lbs. weight on a set of floor scales. From this graph, surface resistance in terms of p.s.i. could be calculated.

TABLE IV.6 SURFACE RESISTANCE - ANALYSES

Date	Source of Variation	S.S.	dF	M.S.	F	F req. & Result
2.2.66	Habitat	155,585	1	155,585	52.5	** 4.0 (7.1)
	Aspect	3,920	1	3,920	1.3	N.S. "
	Interaction	20	1	20	-	N.S. "
	Residual	225,272	76	2,964		
	TOTAL	384,797	79			
15.3.66	Habitat	10,215	1	10,215	39.5	** 4.0 (7.1)
	Aspect	344	1	344	1.3	N.S. "
	Interaction	69	1	69	-	N.S. "
	Residual	19,656	76	259		
	TOTAL	30,284	79			

TABLE IV.7 PATTERN OF SURFACE RESISTANCE - MEANS (p.s.i.) and S.E.s.

Dates	ASPECTS				HABITATS			
	Sunny	vs.	Shady	SIG	Path	vs.	Slope	SIG
2.2.66	353		339	N.S.	390		302	**
(0.25 in.^{2})	S.E.9				S.E.9, d.05(.01) 24(32)C.V.2.5%			
15.3.66	639		598	N.S.	732		596	**
(0.1 in.^{2})	S.E.25				S.E.25,d.05(.01)72(96)C.V.4.1%			

The sunny aspect resistance means were higher on both occasions than the shady face means, but this difference did not reach a significant level. On the other hand it was quite clear that surface soil on the path habitat offered more resistance to penetration than that on the slope habitat on both occasions.

Since soil moisture studies indicated a moister top soil on the paths, it seems that differences in resistance at the surface were the result of differences in soil compaction rather than in moisture. This conclusion supports the penetrometer results which indicated large resistance differences between path and slope within the top 2" of soil.

(c) Bulk Density -

Further confirmation of habitat differences in the structure of soil near the surface was sought through a study of bulk density patterns. Over the four habitats 144 cores were collected, each measuring 6 c.m. in length and 1.7 c.m. diam. These cores were subdivided to give samples from depths of 0-2 c.m. (0-0.8") 2-4 c.m. (0.8-1.6") and 4-6 c.m. (1.6-2.4"). Bulk density, defined as oven dry weight per unit volume of soil, was calculated for each.

TABLE IV.8 BULK DENSITY-ANALYSES

Aspect	Source of Variation	S.S.	dF	M.S.	F	F req. and Result
Sunny	Habitats	0.02	1	0.02	2.66	N.S. 4.00 (7.08)
	Depth	0.98	2	0.49	81.67	** 3.15 (4.98)
	Residual	0.43	68	0.006		
	TOTAL	1.43	71			
Shady	Habitats	0.01	1	0.01	1.14	N.S. 4.00 (7.08)
	Depth	0.94	2	0.47	52.22	** 3.15 (4.98)
	Residual	0.60	68	0.009		
	TOTAL	1.55	71			

TABLE IV.9 PATTERN OF BULK DENSITY-MEANS (gms./c.c.) and S.E.s.

Aspect	Depth	Path	Slope	Means	Significance
Sunny	0-2 cm.	0.98	1.00	0.99	S.E. 0.02
	2-4 cm.	1.09	1.04	1.07	d.05(.01)0.06(0.07)
	4-6 cm.	1.30	1.24	1.27	C.V. 1.7%
	MEANS	1.13	1.09		
Shady	0-2 cm.	0.92	0.97	0.95	S.E. 0.02
	2-4 cm.	1.01	1.07	1.04	d.05(.01)0.05(0.07)
	4-6 cm.	1.26	1.18	1.22	C.V. 1.8%
	MEANS	1.06	1.07		

The results indicate that, taking the top 6 cm. as a whole, there was apparently no significant difference in density between path and slope habitats. Higher bulk density values on the path at 4-6 cm. were offset by lower values near the surface. Within all habitats, density showed a significant and progressive increase from the surface down to 6 cm.

Experimenting on a similar soil type, Edmond (1958 a) found that bulk density increased down to 4-6 cm., where a "pan" was formed. Overall bulk density was increased as the intensity of treading increased.

There is no obvious explanation for the failure to find significant habitat differences in bulk density. It appears that the compaction indicated by soil resistance trials lies at about 1$\frac{1}{2}$" rather close to the surface. This conclusion is in agreement with the results of Edmond (1958 a), Keen and Cashen (1932), Tanner and Mamaril (1959).

D. DIFFERENTIAL BEHAVIOUR OF GRAZING SHEEP

The formation and maintenance of a pasture community type is intimately linked to the behaviour of the animals which graze it. They affect structure and composition in many diverse ways but their activities can conveniently be classified into grazing, treading and excretion effects. The fundamental importance of these activities has been stressed many times and a few notable examples are given in the following discussion.

(i) Grazing

A dramatic illustration of the potential effects of grazing on pasture composition was given by Jones (1933). He was able to swing composition in any desired direction by controlling the time and intensity of grazing in relation to seasonal growth patterns.

If offered a variety of species from which to graze, stock tend to show distinct preferences. Similarly if offered a choice of pasture communities, they are likely to overgraze the one most attractive to them, (e.g. Hunter 1962). To determine whether microcommunity differences were sufficient to influence the pattern of sheep grazing was the purpose of direct observations made on unrestricted sheep during periods in April and June, 1966.

On each face a plot was divided into path, bank and slope communities with securely-pegged cord. The amount of time sheep spent grazing each was observed from the opposite face with the aid of binoculars. For the most part grazing was normal and the average time spent continuously on each community was about 15 seconds. Numerous delays were caused by the sheep resting or by an absence of sheep on the plots.

(ii) Treading

Evidence that treading can exert a selective influence on a pasture community by the elimination of those species not structurally adapted to it, has come from both observation and direct measurement. Bates (1935) recorded a zonation of composition across footpaths, and after trials, concluded that the prime cause of the zonation was puddling. He suggested that it was the cryptophytic life-form which imparted tolerance to a number of species. Davies (1938) found a generally consistent composition of pasture occupying road verges, footpaths, stock tracks and gateways. Edmond (1960, 1963, 1964) measured compositional changes under controlled conditions in which treading was isolated from the effects of grazing and excretion.

Treading may damage plants directly by abrasion of foliage or indirectly through the compaction and puddling of the soil. Topgrowth may be affected by damage to the growing point and root growth by greater soil resistance to root penetration or by loss of air and moisture permeability.

Attempts were made to assess the pattern of treading during observations on grazing behaviour. The 15 second unit was allocated to the community on which the sheep were standing for most of the time. Since they frequently straddled two communities at once this procedure was sometimes arbitrary.

(iii) Excretion

Sears and his associates (Sears and Newbold 1942, Sears, Goodall and Newbold 1948, Sears and Thurston 1952) found that a high level of soil fertility under pasture depended on the rapid turnover of materials engendered by the harvest, conversion and elimination of grazing animals.

The distribution of dung over the three types of community was assessed at three-weekly intervals during the autumn. It was collected from all plots, oven-dried and weighed. Urine patches did not show up clearly enough to warrant their recording.

Community comparisons for grazing preferences, treading and excretion are illustrated in Figs. IV.7 and IV.8. The relative surface areas of these three habitat types are also shown. Raw data appears in the Appendix, Tables 19 and 19b.

Total grazing and treading time was allocated between the three types of community and the percentage of these on each type was compared with the percentage of total surface area.

Grazing occurred on all three communities but the preferences for each were apparently different. On both aspects the slope community seemed to be the most attractive and the bank community least attractive. It was noticeable that the path community was preferred more in relation to other communities on the sunny aspect, where composition differences were more exaggerated. Grazing within each community appeared to be even, although the transition zone between path and slope came in for more intensive grazing, than anywhere else.

The amount of treading received by each type of community is markedly different. Path communities receive the highest intensity, and bank communities receive very little. It was observed that sheep tend to stand on the paths for grazing not only these communities but also while grazing the lower half of the slope and the upper fringe of the bank communities. The latter is also grazed from below and the treading which it receives is infrequent.

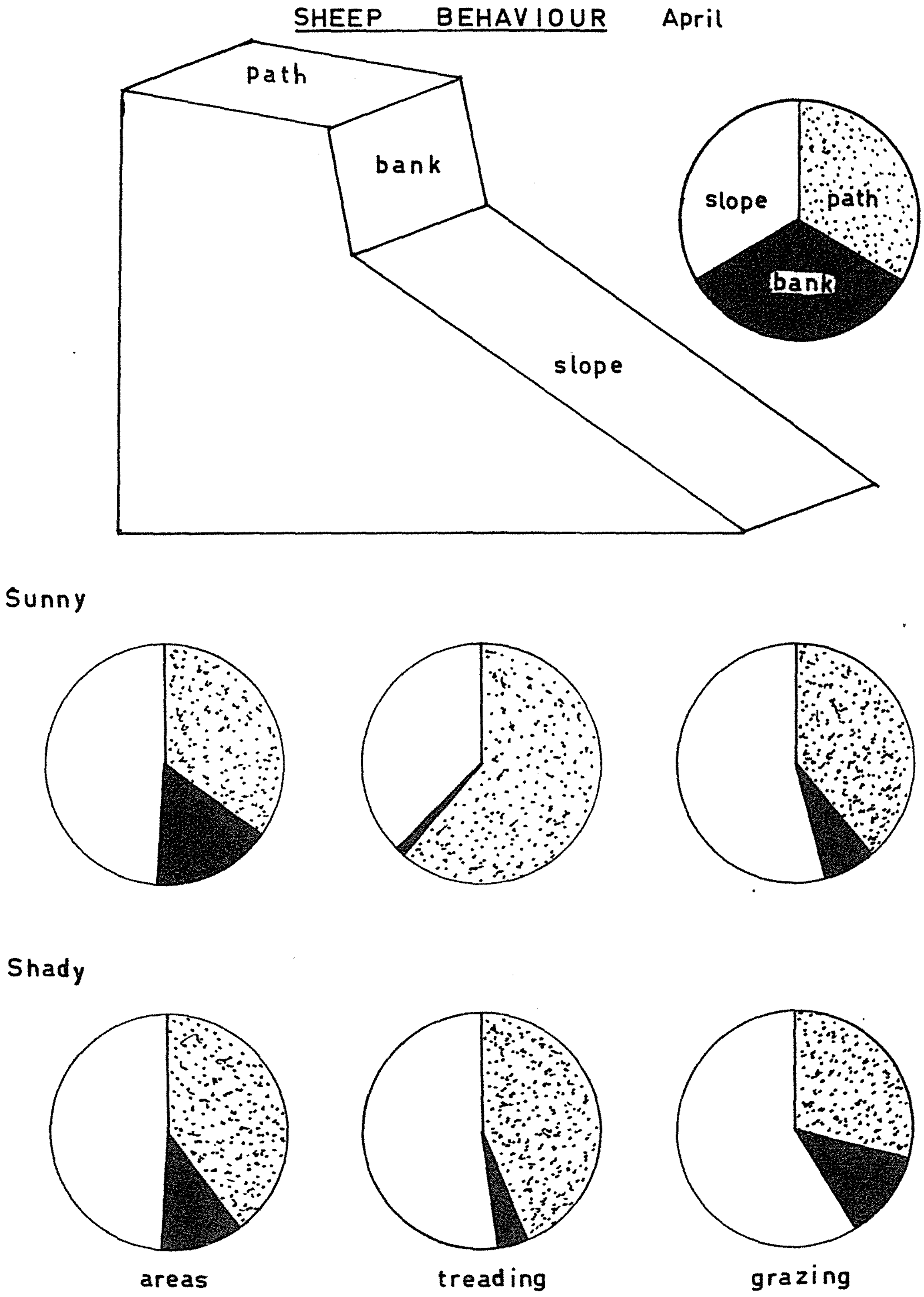


Fig.IV.7 Influence of Sheep Behaviour - April

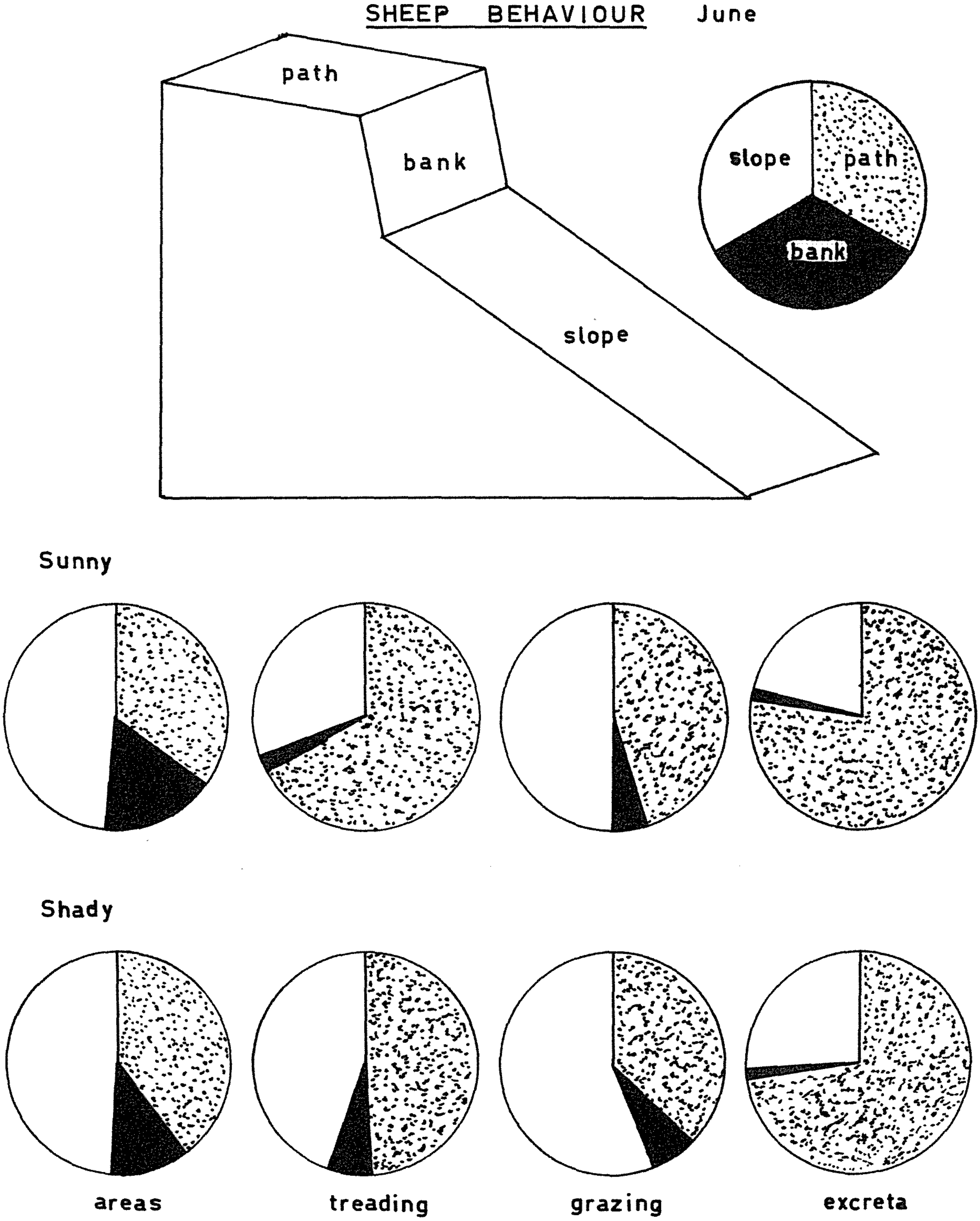


Fig. IV.8 Influence of Sheep Behaviour - June

Even more striking is the differential treatments of community types in the distribution of excreta. Fully 75% of the dung was either deposited or moved to the paths, which accounted for just 34% of the total ground surface area. The bank community which covered 13% of the total area received about 1% of the dung.

E. DISCUSSION ON HABITAT VARIATION

Habitat studies were confined to the Massey site but for a number of reasons it was considered that the conclusions drawn were also applicable to the other sites sampled.

The soil type at Massey is of comparatively heavy texture and high fertility. Habitat differences in soil structure caused by treading may be higher than elsewhere but soil moisture and fertility differences are likely to be smaller. The tracking pattern and unit development is the least intense, with the exception of Waitarere, so that the habitat variation caused by stock behaviour on the Massey site is probably exaggerated on the other sites. The fact that pattern within the pasture is less obvious here seems to support this view.

The habitat study was divided into two categories: below ground and above ground. Significant differences were found to occur between the three defined habitat types which were consistent on both aspects.

Soil profiles were superficially similar under slope and path communities. Differences became apparent after various tests but these were confined to the A horizon and occurred particularly within the top few inches of soil. Root profiles under these community types were similar in main features, but the root distribution within the top 8" appeared to be more even under the path.

Moisture profiles indicated significant habitat differences at about 2" which evened out by 6". Moisture levels under the path community remained significantly higher over the driest part of the year, probably as a result of higher moisture inflow rather lower evapo-transpiration.

Soil resistance trials indicated a zone of greater soil compaction under the path community. Bulk density results showed this zone to lie at about 2".

Grazing sheep apparently affected the different communities in different ways. The slope community received slightly heavier grazing than the path while the bank was lightly grazed. The order of most intensive treading was path, slope, bank. A large proportion of the total excreta was deposited on the path community.

In the absence of any knowledge of pasture composition it would be possible from the above results to make some inferences about likely composition differences in the three habitats. Since variation in the habitats is one of degree, variation in community composition would be expected to be mainly quantitative. The path habitat offers a higher moisture regime over the summer and a higher level of fertility. Species taking advantage of these conditions should be able to withstand more effectively the consequences of direct treading and a slightly more compacted topsoil.

Those species "preferentially" occupying the slope habitat need to withstand drier and less fertile conditions. Grazing may be slightly heavier but trampling less and therefore the soil better aerated. These advantages and disadvantages are exaggerated on the bank. Conditions on the slope habitat lie intermediate between those on path and bank, therefore it would be expected that more species would find conditions suitable, than in either of the other more specialised habitats. Species diversity would be expected to be higher therefore on these areas.

CHAPTER V. GENERAL DISCUSSION AND SUMMARY:

CORRELATION OF VEGETATION AND HABITAT

The ultimate aim of pattern analysis must be separate out from the multi-factorial environment those factors which through their variation from place to place cause pattern within the community. The more factors for which quantitative data are available the more confidently can conclusions be drawn as to which are important and which are of little account. Since a relatively great amount of time and labour is needed for the collection and multi-variate analysis of data on a large number of variables, few such comprehensive studies have been published. (e.g. Hughes and Lindley 1955, Patten 1963).

When such detailed treatment is unwarranted, empirical evidence largely determines upon which habitat variables emphasis is placed. Greig-Smith (1961) suggested that quantitative pattern analysis is more likely to succeed in relatively homogeneous vegetation occupying a relatively uniform habitat, than where major habitat differences cause striking variation in the vegetation. In the latter case it may be difficult to isolate the significant factors from those merely correlated with them.

In the project described here, five facets of habitat variation were studied. Quantitative differences were detected between three replicated slope zones for; soil moisture over the summer, soil resistance near the surface, comparative sheep treading and grazing pressure, and residue received. These factors varied in concert, and it was outside the scope of this study to isolate the impact of each or to establish objectively causal relationships between habitat variables and species patterns.

Circumstantial evidence to assist in pattern interpretation is derived from two main sources: published information on the comparative ecologic requirements and tolerances of each species, and observations on variation within slope zones.

Much literature dealing with the autecology of various pasture species is available, but there has been far less, precise work published dealing with relations between species performing under normal pasture conditions. (e.g. Kershaw 1959). Information used therefore, is derived mainly from ecological studies and observations carried out in the western part of the North Island by Levy (1951), Madden (1940), and Suckling (1954, 1959, 1960). Most of their conclusions were drawn from large scale comparisons but there seems to be no reason why they should not apply to the small scale of interest in this study.

To begin with it is apparent that the five sites can be ranked according to soil fertility and moisture. According to overall pasture composition, there is a progressive decline in these major ecologic controls (Levy 1951) in the order; Hillsborough, Massey, Waitarere, Kimbolton, Manakau, as marked by the decline in abundance of perennial ryegrass and white clover, the Poas, crested dogstail, plantain and moss. A corresponding progressive increase was shown by sweet vernal, browntop, hawkbit, annual clovers, Notodanthonia spp. and ratstail. Similarly, sunny and shady aspects at each site were distinguished by composition differences. Except at Hillsborough and Massey where physical differences between aspects were relatively slight, the perennial ryegrass group was noticeably more abundant on the shady face and the latter group more abundant on the sunny.

The main interest however, lies in differences between demarcated slope zones or habitats.

Path habitats were found to carry a moister soil and since most of the sheep residue landed here, it was of higher fertility. The path community was subject to greater treading, manifest by compaction near the soil surface, but possibly due to either fouling or the relatively unpalatable species present, was grazed a little less intensively than the slope. Two species which invariably thrived in this zone were perennial ryegrass and white clover. This pattern was consistent over the whole fertility range of sites, even though dominant roles were assumed by browntop at Waitarere and by sweet vernal at Kimbolton and Manakau. It appears as though the path habitat conditions were more specialised than elsewhere. Not only were there fewer species, but only five showed a significantly higher relative abundance in this zone in any transect - i.e. perennial ryegrass, white clover, browntop, sweet vernal, and Poa annua.

The reason for this is probably twofold - the more favourable soil conditions induce stronger competition within the community, and species intolerant of treading damage are suppressed. Perennial ryegrass and white clover "favoured" the paths throughout but although major pasture components in all transects, browntop and vernal have a greater relative abundance on the paths only at Waitarere, Kimbolton and Manakau. It seems that their poorer showing in this zone at the other two sites is due to the vigorous growth of perennial ryegrass and white clover, allied perhaps to critical treading damage.

Evidence that treading may have a selective influence is provided by observation and supported by the raw data. Stocking rates at Hillsborough and Massey are slightly higher and at both these sites there are signs of zonation across the paths. In the centre where treading would be heaviest, there was more bare ground, with the perennial ryegrass - white clover community gradually thickening toward the inner and outer edges. Furthermore, about 2" from the outer edge there was often an abrupt change to browntop which tended to "spill" over onto the path from its dominating position on the bank. On the inner side of the path, the transition was more gradual. A similar zonation associated with decreasing intensity of treading on footpaths was described by Bates (1935). The same author as well as Davies (1938) and Edmond (1960) ranked perennial ryegrass as being relatively tolerant to treading and white clover as a quickly-recovering species. Poa annua is recognised as a very effective volunteer on heavily trodden ground. A very slight zonation across the paths was also apparent at Kimbolton, but on the coarser textured and drier soils at Waitarere and Manakau there were no indications. This suggests that treading was not a significant cause of pattern on these sites.

The bank represented the other habitat extreme. Preliminary trials gave no indication of soil resistance differences from the slope but on the two occasions it was measured, soil moisture on the bank was significantly less than on the slope. The bank community appeared to be least affected by grazing and treading and received little if any stock residue.

The relatively dry, infertile and unstable surface soil conditions "favoured" a characteristic and small group of grasses - in particular browntop, chewings fescue, the Notodanthonias and ratstail. On the Hillsborough, Massey and Waitarere sites there was an even distribution of species but at Kimbolton and Manakau there were distinct zonations even although this was the narrowest habitat. Along the outer edge of the path and top part of the bank, chewings fescue, Notodanthonias and hairgrass were concentrated, while the mid and lower portions were mainly browntop. Although never a major pasture component, cocksfoot consistently showed a higher abundance in the mid to lower bank habitat in nearly all transects, as did Yorkshire fog at Hillsborough and Massey. The reasons for these narrow strips of cocksfoot and fog are not known but there is possibly a washing down of excreta or soil nutrients from above. Corresponding to the abrupt changes in slope, transitions from path to bank and bank to slope communities frequently were marked in the data by a sharp decline in the number of browntop hits and rises in perennial ryegrass, sweet vernal, flatweeds or moss.

Conditions in the slope habitat were intermediate between the path and the bank for soil moisture and fertility and stock treading. The community was perhaps more intensively grazed than the other two. The full complement of species was generally represented on the slope, indicating the less specialised nature of the habitat. Species which showed maximum relative abundance in this zone were those whose requirements lay between the two previous groups, such as; sweet vernal, crested dogstail, annual clovers, flatweeds, moss and many minor species such as selfheal, mouse-eared chickweed and Australian linseed. A relatively high proportion were annuals and biennials.

In no transect did significant pattern within the slope community appear. Sears (1956) suggested that a gradation from high to low fertility demanding species from the path to the bank communities was typical. This type of zonation was absent, the apparently random distribution of species suggesting instead, uniform soil moisture and fertility conditions throughout. Stock effects also appeared to be uniform over the whole community. Even on those sites where paths were further apart, there was no sign of a "high tide mark" representing the height to which sheep could conveniently graze from the path.

The development and maintenance of these typically diverse and dynamic microcommunities may largely depend on a moderate to heavy grazing pressure allied to a continual transfer of moisture and nutrients to the path below.

The return of excreta is low and in combination with soil disturbance caused by sliding hooves probably contributes towards a lack of vigor in the dominant species. Opportunities are thus created within the community for short-lived and low-growing light-demanding species. The greater lability of this community was illustrated by the resampling, after four months, of the Hillsborough and Massey transects. It was obvious that most of the change during that period had occurred in slope communities, while the others remained much as before.

In this discussion, attempts have been made to determine which habitat variables cause the patterns shown by individual species, whose combination forms the characteristic types of microcommunity occupying each type of slope zone. The basic cause appears to be a gradation of soil moisture and fertility associated with ground surface configuration and rising from bank and kerb to slope to path habitats. These differences are accentuated by the differential behaviour of grazing animals.

The bank community is the least disturbed by stock so that species which grow most strongly on the dry soil can dominate this habitat. On the slope, heavy grazing and soil disturbance, in association with the transfer of nutrients to the path, encourage a diverse and labile community. The more favourable soil conditions on the path enable rapidly growing species to reach a high degree of dominance. On some sites this may be encouraged by the continual suppression of species unable to withstand treading.

PRACTICAL IMPORTANCE

The complexity of hill country pastures on both macro and micro scales is widely recognised, yet few attempts have been made to analyse the causes of this using quantitative ecological techniques. Information on pattern changes with such management practices as oversowing, topdressing and increased stocking would seem to be of much practical value. Even although modern farming methods are capable of inducing radical changes in composition, marked variability is likely to remain a characteristic feature of pastures on more steeply sloping ground. In this study, relative differences between communities remained similar over the whole range of sites. As soil conditions became less favourable, the predominance of perennial ryegrass on the paths gave way to sweet vernal, while browntop moved in to replace the latter on the less favourable slope habitat. Lesser species accompanied changes in dominance to maintain quantitative community differences.

The work of Suckling (1954, 1959) at Te Awa provides a guide to the likely affect of improvement practices on pasture variability. Oversowing with clovers, topdressing and increased stocking rates caused composition changes on a number of broad habitat types, e.g. sunny and shady faces, easy slopes, dry knob stock camps and slips. Some species; white, red and sub. clovers, Lotus major, perennial ryegrass and crested dogstail, were encouraged at the expense of others; sweet vernal, Notodanthonias, moss, weeds, and to a lesser degree, browntop, Yorkshire fog and chewings fescue. All habitats were influenced in some way so that although the composition of easy slopes and stock camps became more similar, there was still a considerable amount of variation overall. Composition differences were maintained even if communities become more floristically similar.

It remains to be seen whether small scale habitat pattern will be as much a feature of hill country pastures under intensive management. If so then there may be scope for the development of specialised strains of some of those species at present regarded as second best, e.g. crested dogstail, browntop, some annual clovers and plantain. It is worth noting that at the Massey site, path communities occupied only about 33 per cent of total surface area - and probably even less on the other sites.

SUMMARY

This project dealt with the analysis and causes of pasture pattern associated with microtopographical features generally known as "sheep paths".

A limited survey revealed that well-developed tracking occurred on a range of soil types and relief and under a variety of management systems. Variation between slopes was surprisingly small and all units were readily subdivided into three or four slope zones.

Five sites, each with sunny and shady aspects were selected for study, two of these being resampled after an interval of four months. On each slope restricted random sampling was carried out in bounded transects. Results revealed that many, if not most species in each transect showed a pattern of relative cover that was associated with surface configuration. Statistical analysis confirmed the significance of pattern for many species.

A number of habitat variables were studied on one site and quantitative differences were found between slope zones. Soil moisture and fertility variations are considered to be the basic causes of pattern in the pasture but the differential behaviour of grazing animals probably exaggerates the effect of soil factors to the extent of forming distinct habitats. This gives rise to microcommunities differing not only in composition but often in floristics.

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TRANSECTS. TABLE 1. HILLSBOROUGH - November: SUNNY

Species	Habitat Means (%)					Transformed Means				SIG.	d.05	S.E.
	Total	Path	Kerb	Bank	Slope	Path	Kerb	Bank	Slope			
Browntop	10.5	3.3	16.0	22.1	10.9	10.16	23.60	27.78	19.22	**	4.48	1.30
Per. Rye.	21.8	53.5	8.2	4.7	9.2	47.05	16.56	12.49	17.66	**	3.99	1.15
Sw.Vernal	13.3	6.3	7.9	9.8	20.6	14.45	16.18	18.33	27.01	**	2.54	0.74
Chews.fesc.	2.0	0.2	11.3	3.2	1.0	1.48	19.65	9.52	5.76	**	4.82	1.39
York. fog	5.5	3.3	4.7	8.3	6.4	10.24	12.37	16.46	14.52	N	-	1.29
Cr. Dogstail	6.8	5.2	8.5	6.1	7.5	13.11	16.71	14.23	15.86	N	-	1.32
Cocksfoot	1.1	-	-	5.4	1.0	0	0	13.55	5.57	**	2.74	0.79
*Notodan.spp.	0.5	-	2.8	1.2	0.2	0	9.55	5.41	1.90	*	5.31	1.53
Ratstail	0.7	-	3.8	1.7	0.2	0	10.95	7.19	2.26	**	4.16	1.20
Paspalum	0.6	0.3	0.6	1.2	0.5							
Poa pratensis	1.8	1.2	4.1	2.9	1.5							
Poa annua	1.8	4.5	-	-	1.0	12.25	0	0	5.63	**	1.88	0.55
Poa trivialis	0.8	0.6	-	1.2	1.0							
Goosegrass	0.5	0.2	-	0.7	0.7							
White Clover	8.9	7.5	6.9	6.1	10.9	15.92	15.16	14.34	19.00	N	-	1.42
Suckling Clover	0.5	-	0.6	0.7	0.8							
Lotus	2.1	0.6	3.1	1.5	3.0							
Hawkbit	3.2	0.7	3.8	3.9	4.4	4.36	10.60	10.64	12.01	*	4.38	1.27
Plantain	4.1	3.3	2.5	2.9	5.3	10.39	9.03	9.95	13.25	*	2.62	0.75
Catsear	0.8	-	3.1	1.2	0.7							
Hawksbeard	0.3	-	-	-	0.5							
Dandelion	0.3	0.1	-	0.5	0.5							
Yarrow	3.1	2.7	6.0	4.2	2.6							
Selfheal	0.9	0.6	0.6	1.5	1.1							
Chickweed	1.6	1.7	2.5	1.7	1.3							
Scarl.Pimp.	0.7	0.3	-	0.5	1.1							
Linseed	0.2	-	-	-	0.3							
Moss	5.1	4.0	2.8	6.6	5.9	11.58	7.92	15.04	14.07	N	-	2.22
Bare ground	12.0	9.3	15.7	11.9	12.7	17.72	23.33	19.95	20.84	*	2.96	0.85
Cover Rep.	1.69					1.88	1.47	1.62	1.65			
No. of species	28	21	20	25	28	*Notodanthonia unarede.						

TABLE 2. HILLSBOROUGH - November: SHADY

Species	Habitat Means (%)					Transformed Means				SIG.	d.05	S.E.
	Total	Path	Kerb	Bank	Slope	Path	Kerb	Bank	Slope			
Browntop	7.3	1.5	12.0	15.7	7.9	6.92	20.32	23.42	16.72	**	1.91	0.56
Per. Rye.	24.9	53.8	9.2	8.7	13.7	47.12	17.83	17.20	21.70	**	3.80	1.10
Sw.Vernal	11.3	6.5	7.7	8.5	15.6	14.56	16.30	16.69	23.22	*	5.80	1.68
Chews. fesc.	2.3	0.1	16.6	2.7	1.3	1.05	24.16	9.31	6.07	**	3.67	1.07
York. fog	8.6	7.3	8.5	15.5	7.6	15.52	16.42	23.88	16.03	*	6.00	1.73
Cr.Dogstail	4.6	4.9	4.2	4.6	4.6							
Cocksfoot	0.8	-	-	5.0	0.3	0	0	13.28	3.11	**	2.08	0.60
Notodan.spp.	0.4	-	2.5	1.2	0.1	0	9.11	4.96	0.85	*	5.51	1.58
Ratstail	0.4	-	2.1	1.6	0.1							
Paspalum	0.6	0.2	1.8	1.0	0.6							
Poa pratensis	1.8	-	6.7	3.4	1.7							
Poa annua	2.7	7.0	-	0.6	0.9	15.36	0	2.18	5.17	**	4.16	1.20
Poa trivialis	0.8	1.2	0.7	0.8	0.7							
Goosegrass	0.4	0.2	-	0.2	0.6							
White clover	7.7	7.7	8.5	5.8	8.0	16.12	16.57	14.07	16.42	N	-	0.90
Suckling clover	0.4	-	-	-	0.7							
Lotus	1.9	0.3	3.5	2.2	2.6							
Hawkbit	2.9	1.0	3.2	4.4	3.6	5.23	8.81	10.83	10.86	N	-	1.96
Plantain	6.6	4.3	1.8	4.0	9.6	12.00	7.96	11.01	17.98	*	4.72	1.37
Catsear	0.7	-	1.8	-	1.2							
Hawksbeard	0.3	0.1	-	-	0.6							
Dandelion	0.8	0.1	-	0.6	1.4							
Selfheal	1.0	0.7	0.4	0.6	1.4							
Yarrow	2.7	1.3	5.3	4.2	2.6	6.49	13.07	11.48	9.32	*	3.20	0.91
Chickweed	0.6	0.4	1.1	1.0	0.6							
Scarlet pimpernal	1.3	0.4	-	1.6	1.9							
Linseed	0.1	-	-	-	0.3							
Moss	6.2	1.2	2.5	5.8	10.1	6.39	7.64	13.42	18.49	*	6.93	2.00
Bare ground	8.3	5.2	11.7	8.5	9.3	13.11	18.20	16.84	17.73	N	-	1.93
Cover Rep.	1.73					1.97	1.57	1.84	1.61			
No. of species	28	21	20	24	28							

TABLE 3. HILLSBOROUGH - March: SUNNY

Species	Habitat Means					Transformed Means				SIG.	d.05	S.E.
	Total	Path	Kerb	Bank	Slope	Path	Kerb	Bank	Slope			
Browntop	15.1	5.9	24.4	32.3	14.3	13.86	29.61	34.45	22.18	**	6.29	1.82
Per. Rye,	18.7	50.6	4.6	1.8	6.8	45.34	12.24	6.36	14.96	**	6.17	1.78
Sw. Vernal	9.9	3.9	3.3	5.3	16.1	11.26	10.32	13.35	23.60	**	3.79	1.09
Chews.fesc.	3.1	0	15.5	5.8	1.9	0	23.15	13.80	7.95	**	2.45	0.71
York. fog	4.7	4.0	2.0	7.8	4.7	11.57	6.22	16.21	12.39	N	-	2.09
Cr. Dogstail	4.8	3.8	4.6	2.3	6.1	11.14	12.30	7.24	14.09	N	-	2.33
Cocksfoot	2.0	0	0.7	8.3	1.8	0	2.78	16.88	7.58	**	5.68	1.64
Notodan.spp.	1.1	0	7.6	1.0	0.6	0	15.94	4.38	4.21	**	5.33	1.54
Ratstail	1.6	0	6.9	4.3	0.8	0	14.71	11.70	4.35	**	7.24	2.09
Paspalum	1.5	1.3	2.0	3.0	1.0							
Poa pratensis	2.3	2.6	1.0	1.5	2.5							
Poa annua	0.9	2.7	0	0	0.2	9.39	0	0	1.48	**	3.25	0.94
White Clover	12.3	12.9	10.2	7.6	13.6	21.03	18.61	16.04	21.44	N	-	1.47
Suckling Clover	1.0	0	2.3	0.3	1.6							
Lotus	2.3	1.4	0.3	2.0	3.2							
Hawkbit	4.3	1.4	5.3	3.3	6.2	5.74	12.54	10.45	14.32	N	-	1.71
Plantain	4.6	4.6	1.0	4.3	5.5	12.34	4.69	12.00	13.45	*	5.16	1.49
Catsear	1.7	0	2.6	1.1	2.1							
Hawksbeard	0.5	0	0	0	1.0							
Dandelion	0.3	0	0	0	0.5							
Selfheal	1.3	0.4	3.0	1.3	1.4							
Yarrow	2.0	2.4	0.7	2.0	2.0							
Chickweed	0.9	0.3	0.7	1.5	1.2							
Scarlet Pimpernal	0.3	0	0	0	0.7							
Linseed	0.2	0	0	0	0.5							
Moss	2.9	1.8	1.3	3.3	3.8	7.66	5.35	7.86	11.25	N	-	2.02
Bare ground	14.0	10.9	19.0	15.5	14.2	19.33	25.79	23.18	22.08	**	1.88	0.54
Cover Rep.	1.57					1.71	1.40	1.57	1.53			
No. of species	26	17	21	23	26							

TABLE 4. HILLSBOROUGH - March: SHADY

Species	Habitat Means					Transformed Means				SIG.	d.05	S.E.
	Total	Path	Kerb	Bank	Slope	Path	Kerb	Bank	Slope			
Browntop	10.6	4.3	17.0	23.2	9.9	11.98	24.40	28.67	18.30	**	1.96	0.57
Per. Rye.	22.0	47.7	6.6	7.6	12.8	43.61	15.10	15.96	20.93	**	2.94	0.85
Sw. Vernal	9.5	4.4	6.6	5.9	14.1	11.98	14.82	14.12	22.05	**	3.38	0.98
Chews. fesc.	3.1	0.4	21.8	4.3	1.4	2.18	27.63	11.87	5.42	**	6.24	1.80
York. fog	9.1	8.5	11.1	15.4	7.4	16.95	19.35	23.48	15.78	**	2.86	0.82
Cr. Dogstail	2.7	3.7	0.7	1.8	2.7	10.96	2.97	7.83	9.43	N	-	1.83
Cocksfoot	1.4	0	0	6.6	1.0	0	0	14.88	5.81	**	2.20	0.63
Notodan. spp.	0.7	0	4.8	1.2	0.3	0	12.67	6.16	2.53	**	5.29	1.53
Ratstail	0.9	0.3	3.0	2.7	0.4	1.71	9.53	9.46	2.10	*	5.16	1.49
Paspalum	1.4	1.0	0.7	1.8	1.5							
Poa pratensis	0.6	0	1.5	0.8	0.7							
Poa annua	1.4	4.6	0	0	0	12.38	0	0	0	**	0.81	0.24
White Clover	11.2	11.7	11.4	10.9	11.1	20.00	19.64	19.28	19.42	N	-	0.76
Suckling clover	0.6	0	0.7	0	1.2							
Lotus	1.8	0.8	0.4	0.4	3.0							
Hawkbit	4.2	1.7	7.7	5.3	4.8	7.40	16.35	12.56	12.54	*	4.80	1.39
Plantain	7.1	5.6	1.1	4.7	9.6	13.65	3.15	12.55	18.11	**	6.88	1.98
Catsear	0.9	0	2.6	0	1.4							
Hawksbeard	0.1	0	0	0	0.2							
Dandelion	0.7	0	0	0	1.4							
Selfheal	1.2	2.2	1.5	0.6	2.3							
Yarrow	2.0	1.0	0.4	1.2	1.5							
Chickweed	0.1	0.3	0	0	0							
Scarlet pimpernal	0.9	0.5	0	1.4	1.1							
Linseed	0.3	0	0	0.6	0.4							
Scot.Thistle	0.2	0	0	0	0.5							
	5.5	1.4	0.4	3.5	9.4	6.53	1.81	11.09	17.82	**	4.45	1.29
Bare Ground	11.9	8.3	17.8	10.4	13.2	16.81	25.16	18.93	21.27	*	3.99	1.15
Cover Rep.	1.63					1.80	1.50	1.82	1.52			
No. of species	27	18	19	20	25							

TABLE 5. MASSEY - December: SUNNY:

Species	Habitat Means				Transformed Means			SIG	d.05	S.E.
	Total	Path	Bank	Slope	Path	Bank	Slope			
Browntop	20.7	12.6	36.3	20.8	20.80	37.10	27.11	**	2.91	0.74
Perennial Rye.	17.0	39.2	6.5	7.7	38.87	14.76	16.03	**	3.66	0.93
Sw. Vernal	11.5	9.0	10.1	13.3	17.29	18.65	21.37	N	-	0.81
Chews. fesc.	0.7	0	3.4	0.3						
York. fog	6.0	3.7	10.3	6.0	11.07	18.10	14.12	**	3.22	0.82
Cr. Dogstail	3.3	4.0	2.4	3.2	11.58	8.35	10.40	N	-	1.03
Cocksfoot	1.2	0.1	4.3	0.9	1.05	12.15	5.10	**	3.05	1.03
*Notodan. spp.	1.2	0	2.2	1.6	0	8.57	7.22	**	2.78	0.70
Poa pratensis	1.2	0.7	1.0	1.5						
Poa annua	1.2	3.2	0.5	0.3	10.31	2.01	2.33	**	3.30	0.84
Poa trivialis	0.5	0.4	1.4	0.2						
Goosegrass	0.3	0	0.5	0.3						
White Clover	13.0	18.2	8.2	11.4	25.18	16.36	19.58	**	3.41	0.87
Suckling Clover	0.8	0	0	1.5						
Hawkbit	5.4	1.7	4.1	7.8	7.54	11.82	16.24	**	3.91	1.00
Plantain	2.5	2.1	1.0	3.1	8.08	4.99	10.33	N	-	1.98
Catsear	1.9	0	0.2	3.5						
Hawksbeard	0.6	0	0	1.1						
Dandelion	0.7	0.2	0	1.2						
Daisy	0.7	0	0.2	1.2						
Selfheal	1.9	1.0	1.9	2.4						
Chickweed	1.2	0.6	1.7	1.5						
Scarlet pimpernal	0.4	0.4	0.7	0.3						
Speedwell	0.3	0	0	0.5						
Linseed	0.3	0	0	0.6						
Moss	5.4	2.6	3.1	7.6	9.40	9.22	16.03	**	3.47	0.88
Bare ground	8.9	8.6	9.1	9.1	17.05	17.65	17.63	N	-	0.17
Cover Rep.	1.69				1.86	1.65	1.62			
No. of species	26	17	21	26	*Notodanthonia clavata					

TABLE 6. MASSEY - December: SHADY

Species	Habitat Means				Transformed Means			SIG.	d.05	S.E.
	Total	Path	Bank	Slope	Path	Bank	Slope			
Browntop	19.9	13.5	30.9	21.0	21.47	33.67	27.38	**	4.22	1.08
Perennial Rye.	16.2	36.2	6.1	5.9	36.82	14.35	14.06	**	3.39	0.86
Sw. Vernal	15.4	9.9	15.4	19.1	18.22	23.03	26.09	*	3.86	0.98
Chews. fescue	0.1	0	0.8	0						
York. fog	6.1	5.0	7.7	6.4	12.85	16.15	14.56	N	-	0.98
Cr. Dogstail	3.3	3.1	3.6	3.3	10.02	10.88	10.67	N	-	0.36
Cocksfoot	0.7	0	3.3	0.3	0	10.35	1.91	*	5.16	1.31
Notodan. spp.	0.4	0	1.7	0.3	0	7.16	2.33	**	2.61	0.67
Poa pratensis	0.8	1.0	2.5	0.1						
Poa annua	1.2	2.6	0	0.7	9.10	0	4.18	*	6.77	1.72
Poa trivialis	0.1	0	0.6	0.1						
Goosegrass	0.2	0	0.6	0.2						
White Clover	13.1	18.4	6.1	11.6	25.46	14.23	19.37	*	7.88	2.00
Suckling Clover	0.4	0.2	0	0.7						
Hawkbit	5.3	1.8	5.0	7.7	7.75	12.85	16.11	**	1.39	0.36
Plantain	3.5	2.9	1.1	4.5	9.86	5.14	12.38	N	-	1.46
Catsear	1.3	0	1.1	2.3						
Hawksbeard	0.6	0	0	1.2						
Dandelion	1.0	0.7	0.6	1.3						
Daisy	0.7	0.2	0	1.2						
Selfheal	2.4	1.2	4.1	2.7						
Chickweed	0.7	0.6	0	0.9						
Scarlet pimpernal	0.7	0	2.2	0.7						
Speedwell	0.9	0.1	1.1	1.3						
Linseed	0.3	0	0	0.5						
Moss	4.9	2.5	5.8	6.2	9.03	13.93	14.54	**	1.92	0.48
Bare ground	9.2	9.5	9.4	8.9	18.01	17.94	17.15	N	-	0.98
Cover Rep.	1.60				1.68	1.55	1.58			
No. of species	26	17	20	25						

TABLE 7. MASSEY - April:. SUNNY

Species	Habitat Means				Transformed Means			SIG	d.05	S.E.
	Total	Path	Bank	Slope	Path	Bank	Slope			
Browntop	24.8	16.8	41.4	23.8	24.22	40.32	29.31	**	6.58	1.67
Perennial Rye.	14.6	37.1	3.5	6.5	37.57	10.33	14.71	**	4.44	1.13
Sw. Vernal	9.2	6.8	7.9	10.9	15.07	16.46	19.29	*	2.78	0.71
Chews. fescue	0.9	0	2.3	0.9						
York. fog	4.3	2.1	7.2	4.6	8.13	14.91	12.12	N	-	1.42
Cr. Dogstail	2.5	3.2	2.3	2.1	10.24	8.61	8.74	N	-	0.67
Cocksfoot	1.9	0.4	4.7	1.8	3.06	12.46	5.82	N	-	2.09
Notodan. spp.	1.4	0	3.7	1.4	0	11.34	6.48	**	3.44	0.88
Poa pratensis	1.4	1.0	0.9	1.8						
Poa annua	0.3	1.0	0	0						
White Clover	15.1	23.0	8.4	13.1	28.52	16.77	21.24	**	4.30	1.09
Suckling clover	1.3	0	1.2	1.9						
Hawkbit	7.2	2.2	6.8	10.0	7.21	15.20	18.40	*	8.16	2.08
Plantain	1.8	1.9	0.7	2.1	7.75	2.42	7.70	N	-	1.31
Catsear	2.3	0	0.7	4.0	0	3.85	11.55	**	5.61	1.43
Hawksbeard	0.5	0	0	1.0						
Dandelion	1.1	0.4	0	1.8						
Daisy	0.4	0	0	0.8						
Selfheal	2.9	1.7	2.8	3.5						
Pennyroyal	0.8	0.3	0	1.3						
Chickweed	1.1	1.1	2.1	0.8						
Scarlet pimpernal	0.2	0	0.2	0.3						
Speedwell	0.5	0	0.5	0.9						
Bidibid	0.2	0.1	0.2	0.1						
Linseed	0.3	0	0	0.5						
Moss	3.1	1.0	2.3	4.4	5.45	8.45	12.31	**	3.08	0.79
Bare ground	9.5	11.1	8.3	9.1	19.46	16.74	17.58	N	-	1.00
Cover Rep.	1.63				1.67	1.69	1.59			
No. of species	26	17	20	25						

TABLE 8. MASSEY - April: SHADY

Species	Habitat Means				Transformed Means			SIG.	d.05	S.E.
	Total	Path	Bank	Slope	Path	Bank	Slope			
Browntop	23.9	18.3	36.2	23.7	25.15	36.95	29.26	**	4.64	1.18
Perennial Rye.	14.3	33.2	3.5	5.4	35.28	10.79	13.64	**	4.86	1.24
Sw. Vernal	11.7	7.6	11.5	14.6	15.64	19.74	22.20	N	-	1.27
Chews. fescue	0.3	0	1.6	0						
York. fog	5.3	4.0	9.1	5.0	11.30	17.66	13.17	N	-	1.25
Cr. Dogstail	2.4	2.1	2.9	2.4						
Cocksfoot	0.9	0.1	3.8	0.5	1.21	11.04	2.27	*	6.05	1.54
Notodan. spp.	0.8	0.1	2.9	0.6	1.21	9.54	3.51	*	4.19	1.06
Poa pratensis	1.1	1.0	1.3	1.0						
Poa annua	0.6	1.4	0	0.2						
Poa trivialis	0.1	0	0.5	0						
White clover	14.6	21.1	7.2	12.7	27.33	15.68	20.49	**	4.80	1.22
Suckling clover	0.9	0	0.5	1.6						
Hawkbit	5.8	2.1	5.9	8.3	8.02	14.18	16.55	**	3.68	0.98
Plantain	3.9	2.7	2.1	5.3	9.54	8.36	13.16	*	2.53	0.65
Catsear	1.8	0	0.5	3.4	0	2.27	10.28	**	4.75	1.21
Hawksbeard	0.4	0	0	0.8						
Dandelion	1.0	1.0	0	1.4						
Daisy	0.9	0.5	0	1.4						
Selfheal	2.4	1.6	2.9	2.7						
Pennyroyal	0.2	0	0	0.3						
Chickweed	0.8	0.5	1.1	0.9						
Scarlet pimpernal	0.3	0	1.6	0.2						
Speedwell	0.5	0	0.3	0.9						
Bidibid	0.4	0	1.3	0.3						
Linseed	0.4	0	0	0.6						
Moss	4.2	2.5	2.9	5.8	8.82	9.89	14.10	N	-	1.08
Bare ground	11.0	10.7	9.8	11.5	19.16	18.27	18.51	N	-	1.12
Cover Rep.	1.54				1.58	1.59	1.51			
No. of species	27	17	21	25						

TABLE 9. WAITARERE - SUNNY:

Species	Habitat Means				Transformed Means			SIG.	d.05	S.E.
	Total	Path	Bank	Slope	Path	Bank	Slope			
Browntop	30.6	28.2	30.0	31.6	32.08	33.20	34.16	N	-	0.87
Perennial Rye.	9.3	20.5	3.5	6.3	26.84	10.61	14.52	**	4.80	1.22
Sw. vernal	13.3	11.6	11.7	14.3	9.96	19.51	22.09	N	-	1.19
Chews. fescue	4.2	2.1	8.5	4.0	8.16	16.92	11.48	**	3.86	0.98
York. fog	1.5	2.1	1.1	1.4						
Cr. Dogstail	3.3	4.4	1.1	3.4						
Cocksfoot	1.9	2.5	6.7	0.6	9.07	14.95	3.51	**	4.22	1.08
*Notodan. spp.	1.7	0.2	6.4	1.2	1.60	14.56	6.03	*	6.11	1.56
Ratstail	4.0	1.2	5.7	4.7	5.07	13.76	12.60	*	7.02	1.79
Paspalum	0.8	1.2	0.4	0.8						
Hairgrass	1.0	0	0.7	1.4						
White Clover	8.0	13.3	5.3	6.6	21.40	13.46	14.96	*	4.30	1.10
Hawkbit	8.2	6.0	6.7	9.3	10.76	11.66	17.81	**	1.00	0.27
Catsear	3.3	1.5	6.0	3.5	5.59	14.46	10.66	N	-	2.29
Dandelion	1.5	0.4	0	2.2						
Selfheal	2.5	3.5	3.2	1.9						
Sorrel	3.6	1.0	2.5	4.8						
Moss	1.4	0.2	0.7	2.0						
Bare ground	13.4	14.4	10.7	13.7	22.33	19.27	21.79	N	-	0.84
Cover rep.	1.23				1.34	1.13	1.21			
No. of species	18	17	17	18	*Notodanthonia clavata, N.racemosa					

TABLE 10. WAITARERE - SHADY:

Species	Habitat Means				Transformed Means			SIG.	d.05	S.E.
	Total	Path	Bank	Slope	Path	Bank	Slope			
Browntop	26.5	31.0	33.4	23.0	33.82	34.95	28.54	*	4.97	1.27
Perennial Rye.	11.3	23.9	6.2	7.6	29.22	13.60	15.81	**	6.77	1.73
Sw. Vernal	15.5	10.5	17.4	17.0	18.91	24.55	24.29	**	1.64	0.35
Chews. fescue	1.2	0.8	3.3	0.8	4.19	10.47	4.98	N	-	1.36
York. fog	2.6	2.9	3.9	2.1	9.73	10.74	8.37	N	-	1.57
Cr. Dogstail	4.0	4.6	2.0	4.3						
Cocksfoot	2.5	1.7	4.9	2.2	7.07	13.06	8.64	*	4.55	1.16
Notodan. spp.	0.9	0	2.0	0.9						
Ratstail	2.2	0.2	4.3	2.5	1.48	11.93	9.09	*	6.52	1.36
Paspalum	0.9	0.6	0	1.2						
Hairgrass	0.9	0	0	1.4						
White Clover	10.5	11.7	9.5	10.2	20.00	17.83	18.48	N	-	0.87
Sub. Clover	0.5	0	0.3	0.7						
Lotus	2.3	1.7	1.6	2.7						
Hawkbit	5.7	2.3	6.9	6.7	8.68	14.82	15.07	*	4.30	1.10
Plantain	2.2	3.8	0.7	2.0	11.07	2.34	7.97	*	6.52	1.66
Catsear	1.2	0	0.3	1.8						
Hawksbeard	0.5	0	0.7	0.6						
Dandelion	1.1	0.6	0	1.6						
Selfheal	3.0	2.9	1.3	3.5						
Sorrel	1.1	0	0	1.7						
Linseed	0.8	0.2	0	1.2						
Moss	2.8	0.4	1.3	4.1	2.96	5.25	11.63	N	-	2.26
Bare ground	12.8	13.6	11.5	12.9	21.61	18.91	21.01	N	-	1.40
Cover Rep.	1.30				1.48	1.21	1.26			
No. of species	23	17	18	23						

TABLE 11. KIMBOLTON - SUNNY:

Species	Habitat Means				Transformed Means			SIG.	d.05	S.E.
	Total	Path	Bank	Slope	Path	Bank	Slope			
Browntop	18.5	21.2	17.3	17.5	27.38	24.64	24.75	*	1.69	0.42
Perennial Rye.	1.2	3.1	0.3	0.4	10.15	1.81	2.65	*	6.16	1.57
Sw. Vernal	36.6	45.1	35.2	32.7	42.17	36.54	35.05	*	3.64	0.93
Chews. fescue	7.7	6.3	12.0	7.1	14.35	20.32	15.55	*	3.64	0.93
York. fog	0.7	0.2	0.7	1.0						
Cr. Dogstail	1.8	1.8	1.0	2.1						
Cocksfoot	0.4	0	0.7	0.6						
*Notodan. spp.	4.4	3.3	7.3	4.1	10.50	15.40	11.63	*	2.78	0.70
Hairgrass	2.7	0.6	5.0	3.0	3.58	12.90	9.91	*	4.41	1.13
White Clover	5.7	7.6	4.0	5.3	16.09	11.50	13.30	**	1.50	0.37
Sub. Clover	2.6	2.2	3.0	2.6						
Suckling Clover	1.0	0.2	1.3	1.3						
Hawkbit	7.1	4.1	4.7	9.4	11.61	12.46	17.77	**	1.94	0.49
Catsear	3.7	1.6	3.0	5.1	7.04	9.99	12.60	N	-	1.25
Dandelion	0.2	0	0	0.4						
Selfheal	2.2	1.6	1.3	2.7						
Chickweed	0.4	0.2	0.7	0.4						
Moss	3.1	1.0	2.7	4.2	4.58	9.39	12.01	*	5.05	1.29
Bare ground	14.6	13.5	12.7	15.8	21.55	20.61	23.58	N	-	0.91
Cover rep.	1.25				1.23	1.19	1.28			
No. of species	18	16	17	18	* Notodanthonia clavata, N.unarede					

TABLE 12. KIMBOLTON - SHADY:

Species	Habitat Means				Transformed Means			SIG.	d.05	S.E.
	Total	Path	Bank	Slope	Path	Bank	Slope			
Browntop	15.3	19.8	13.8	13.6	26.22	21.91	21.49	*	3.11	0.79
Perennial Rye.	2.4	4.9	1.6	1.4	12.86	5.61	6.85	*	5.72	1.46
Sw. Vernal	32.2	45.1	26.8	27.6	41.78	31.15	31.46	*	7.00	1.78
Chews. fescue	5.8	6.2	9.8	4.3	14.23	18.19	11.59	N	-	2.59
York. fog	1.3	1.9	2.3	0.7						
Cr. Dogstail	1.9	1.9	1.4	2.1						
Cocksfoot	1.2	0.5	3.2	0.9	3.36	10.07	4.52	*	5.69	1.45
Notodan. spp.	3.7	1.0	7.5	3.7	4.50	15.77	10.80	*	5.22	1.33
Hairgrass	0.6	0.3	1.6	0.5						
White Clover	7.0	6.9	4.8	7.8	15.23	12.32	16.50	N	-	1.40
Suckling clover	0.7	0.5	0.2	1.0						
Lotus	0.6	0.2	2.0	0.2						
Sub. Clover	2.0	0.2	3.9	2.3	1.35	11.24	8.77	*	3.72	1.25
Hawkbit	6.5	4.0	4.3	8.5	11.49	12.02	16.83	**	1.97	0.50
Plantain	1.9	1.6	0.7	2.5						
Catsear	3.0	0.8	2.0	4.4	2.78	6.97	11.88	N	-	2.18
Hawksbeard	0.5	0	0	1.0						
Dandelion	0.6	0.3	0.4	0.8						
Selfheal	3.8	1.8	3.9	4.8	6.44	11.33	12.74	N	-	1.99
Chickweed	0.5	0	1.6	0.4						
Sorrel	0.3	0	0.7	0.2						
Linseed	0.9	0.8	0.2	1.3						
Woodrush	0.7	0.3	1.4	0.6						
Moss	6.5	1.1	6.1	9.4	5.14	14.20	17.68	*	6.41	1.63
Bare ground	10.8	12.5	10.2	10.2	20.69	18.78	18.65	N	-	0.75
Cover rep.	1.44				1.45	1.37	1.45			
No. of species	24	21	23	24						

TABLE 13. MANAKAU - SUNNY:

Species	Habitat Means					Transformed Means				SIG.	d.05	S.E.
	Total	Path	Kerb	Bank	Slope	Path	Kerb	Bank	Slope			
Browntop	37.5	30.3	36.4	42.2	38.4	33.42	36.98	40.59	38.31	**	3.01	0.82
Per. Rye.	2.2	6.8	2.0	1.3	0.9	15.19	8.60	5.31	5.53	*	5.73	1.57
Sw. vernal	17.0	42.3	13.9	11.0	11.0	40.51	23.12	19.39	19.31	**	4.88	1.35
Chews.fesc.	1.9	0.4	11.9	5.7	0.3	2.18	18.93	13.78	2.53	**	7.35	2.02
York. fog	0.9	0.2	0.7	0.9	1.1							
Cr. dogstail	4.1	3.9	2.0	5.3	4.0							
Cocksfoot	0.6	0.2	0	2.1	0.3							
*Notodan.spp.	2.3	0	5.3	5.9	1.6	0	13.08	13.98	7.33	**	2.65	0.73
Ratstail	4.2	0.4	6.6	10.0	3.4	2.18	16.33	18.41	10.56	**	4.09	1.12
Paspalum	0.1	0.2	0	0	0.1							
Hairgrass	2.7	0	5.3	2.5	3.4	0	13.60	7.27	10.59	*	7.66	2.11
Tall fescue	0.3	0	0	0.6	0.4							
White clover	6.5	9.6	3.3	3.2	6.8	18.11	11.93	10.26	15.16	*	4.50	1.24
Sub. clover	1.4	0	0	0.4	2.4							
Hawkbit	9.4	4.3	2.0	4.0	13.5	11.86	10.01	11.18	21.51	**	5.53	1.52
Catsear	5.0	1.5	6.6	1.7	7.0	5.55	13.22	6.10	15.26	N	-	2.46
Sorrel	2.1	0	0	1.7	3.1							
Linseed	0.2	0	0	0	0.4							
Scotch thistle	0.8	0	4.0	0.9	0.7							
Moss	0.9	0	0	0.6	1.3							
Bare Ground	14.5	11.4	17.6	15.5	14.6	19.78	24.68	22.86	22.62	N	-	1.70
Cover rep.	1.50					1.77	1.39	1.54	1.42			
No. of species	20	12	15	18	20	* Notodanthonia clavata						

TABLE 14. MANAKAU - SHADY:

Species	Habitat Means					Transformed Means				SIG.	d.05	S.E.
	Total	Path	Kerb	Bank	Slope	Path	Kerb	Bank	Slope			
Browntop	35.2	27.0	38.9	46.3	32.7	31.26	38.52	42.84	34.78	**	2.57	0.75
Per. Rye.	4.3	11.2	1.9	2.4	2.7	19.59	6.88	8.86	9.65	*	6.97	2.01
Sw. Vernal	19.7	0.4	9.9	13.6	14.4	39.48	18.33	21.75	22.22	**	2.03	0.64
Chews.fesc.	1.8	0.2	13.6	3.2	0.2	1.35	20.92	9.37	1.48	**	5.02	1.45
York. fog	1.7	1.2	0	2.5	1.7							
Cr. Dogstail	1.7	2.6	1.9	0.9	1.7							
Cocksfoot	1.1	0	0	2.9	0.8	0	0	9.79	5.13	**	2.50	0.71
Notodan.spp.	1.1	0	8.0	2.2	0.1	0	15.87	8.48	0.85	**	3.18	0.92
Ratstail	1.5	1.1	8.0	1.8	0.8	4.84	16.13	6.04	3.70	N	-	2.85
Paspalum	0.4	0.2	0	0	0.9							
Hairgrass	2.4	0.7	3.1	2.5	2.9	3.91	10.04	8.87	10.00	*	4.23	1.22
Tall fescue	0.2	0.2	0	0	0.4							
White clover	5.5	8.1	1.9	2.9	6.2	16.37	6.05	9.98	14.56	*	5.70	1.65
Suckling clover	1.6	0	1.9	0.4	2.8							
Lotus	1.0	0	0	2.9	0.6							
Sub. clover	0.5	0	0.6	0.1	0.8							
Hawkbit	8.2	4.0	5.6	6.3	11.3	11.33	13.68	14.57	19.38	N	-	1.89
Plantain	1.5	1.8	0	1.6	1.4	7.55	0	7.22	6.44	N		0.61
Catsear	2.8	0.5	3.1	1.8	4.2	3.29	7.41	7.64	11.79	N	-	2.52
Hawksbeard	0.5	0	0	0	1.0							
Dandelion	0.6	0.2	0	0	1.1							
Daisy	0.3	0.2	0	0	0.5							
Selfheal	1.9	0.4	0	1.2	3.1							
Bidibid	1.6	0	0	1.8	2.3							
Sorrel	1.1	0	0	0.6	2.0							
Linseed	0.5	0	0	0	1.1							
Woodrush	0.2	0	1.9	0.1	0.2							
Moss	1.6	0.2	0	1.8	2.3							
Bare ground	14.8	11.9	17.5	16.9	14.6	20.07	24.79	24.48	22.67	*	3.18	0.92
Cover rep.	1.40					1.51	1.28	1.51	1.33			
No. of species	28	18	14	22	28							

APPENDIX

TABLE 15. SPECIES OCCURRING IN TRANSECTS

Common Name	Botanical Name
Browntop	Agrostis tenuis
Perennial Ryegrass	Lolium perenne
Sweet Vernal	Anthoxanthum odoratum
Chewings Fescue	Festuca rubra var. commutata
Yorkshire Fog	Holcus lanatus
Crested Dogstail	Cynosurus cristatus
Cocksfoot	Dactylis glomerata
Notodanthonia	Notodanthonia spp.
Ratstail	Sporobolus capensis
Paspalum	Paspalum dilatatum
Poa pratensis	Poa pratensis
Poa annua	Poa annua
Poa trivialis	Poa trivialis
Goosegrass	Bromus mollis
Hairgrass	Vulpia bromoides
Tall Fescue	Festuca arundinacea
White Clover	Trifolium repens
Suckling Clover	Trifolium dubium
Lotus major	Lotus pedunculatus
Subterranean Clover	Trifolium subterranean
Hawkbit	Leontodon taraxacoides
Plantain	Plantago lanceolata
Catsear	Hypochaeris radicata
Hawksbeard	Crepis capillaris

Dandelion	Taraxacum officinale
Daisy	Bellis perennis
Selfheal	Prunella vulgaris
Yarrow	Achillea millefolium
Mouse-eared chickweed	Cerastium glomeratum
Scarlet pimpernel	Anagallis arvensis
Creeping speedwell	Veronica serpyllifolia
Sheep sorrel	Rumex acetosella
Scotch thistle	Circium lanceolata
Australian linseed	Linum marginale
Woodrush	Luzula spp.
Pennyroyal	Mentha pulegium
Bidibid	Acaena anserinifolia
Moss	Thiudium furfurosum

TABLE 16. PRELIMINARY SAMPLING (% of SURFACE COVER)

Species	SUNNY			SHADY		
	Path	Bank	Slope	Path	Bank	Slope
Browntop	9.9	38.7	28.2	12.9	36.6	31.9
Peren. rye.	42.7	3.3	7.0	39.5	4.6	7.7
Sw. vernal	7.1	9.2	12.2	7.5	13.7	10.5
York. fog	1.9	11.9	3.9	1.3	10.7	3.5
Cr. dogstail	1.6	4.4	2.5	1.6	1.9	2.1
Cocksfoot	-	2.9	1.4	0.2	5.0	2.8
Notodan. spp.	-	1.7	0.2	-	1.0	-
Poa annua	4.0	-	1.5	5.5	0.7	1.4
White Clover	23.0	5.9	8.9	24.3	5.5	7.0
Hawkbit	5.0	9.0	12.7	4.6	6.9	11.5
Plantain	1.6	1.2	3.0	1.3	0.9	1.4
Catsear	-	2.7	1.4	0.3	2.2	1.4
Selfheal	-	4.3	2.8	0.6	4.6	2.8
Moss	-	4.6	9.7	0.4	6.1	11.2
Bare	8.7	7.7	8.1	8.2	7.6	7.9
Cover Rep.	1.57	1.53	1.48	1.62	1.60	1.53

TABLE 17. COMPARISON OF COVER AND YIELD

SPECIES G = grams H = hits		RAW DATA				PERCENTAGES			
		Sunny		Shady		Sunny		Shady	
		Path	Slope	Path	Slope	Path	Slope	Path	Slope
Browntop	G	18	64	9	27	8.1	38.1	4.2	17.3
	H	41	112	12	36	10.3	28.9	2.9	9.5
Peren.rye.	G	148	15	126	22	66.6	8.9	56.8	14.1
	H	174	26	162	33	43.5	6.7	39.5	8.7
Sw.vernal	G	38	44	49	50	17.1	26.2	22.9	32.1
	H	27	46	43	77	6.7	11.9	10.5	20.0
York. fog	G	2	10	6	6	0.9	6.0	2.8	3.8
	H	5	13	3	6	1.2	3.4	0.8	1.6
Other grasses	G	7	10	11	20	3.2	6.0	5.1	12.8
	H	23	33	18	41	5.8	8.4	4.3	10.6
White clover	G	9	5	13	6	4.1	3.0	6.1	3.8
	H	93	36	91	44	23.2	9.2	22.2	11.5
Flatweeds	G	T	20	T	20	-	11.9	1.7	12.8
	H	37	75	56	87	9.3	19.3	13.6	22.7
Other Weeds	G	-	T	T	3	-	-	0.4	1.9
	H	-	12	23	34	-	3.2	5.5	8.8
Moss	G	-	T	-	2	-	-	-	1.3
	H	-	35	2	23	-	8.9	0.5	6.1
TOTALS	G	222	168	214	156				
	H	400	388	410	383				

TABLE 18. PLOT DIMENSIONS

Zones	SUNNY						SHADY						Zone Totals	
	LA		LB		LC*		RA		RB*		RC			
	ft^2	%	ft^2	%	ft^2	%	ft^2	%	ft^2	%	ft^2	%	ft^2	%
Path	50	33	43	28	80	35	69	33	105	32	125	40	472	34
Bank	27	18	18	12	37	16	23	11	43	13	35	11	183	13
Slope	74	49	95	60	114	49	116	56	182	55	151	49	732	53
TOTALS	151	100	156	100	231	100	208	100	330	100	311	100	1387	100

* Transects.

TABLE 19. BEHAVIOUR EFFECTS ON HABITATS

(a) Grazing and Treading -

Habitat	SQ.FT. AREA	UNITS 15 Sec.				AREA	PERCENTAGES			
		Grazing		Treading			Grazing		Treading	
		Apr.	June	Apr.	June		Apr.	June	Apr	June
SUNNY										
Path	80	153	98	314	194	34.6	39	45	61	66
Bank	37	28	10	5	9	16.0	7	5	1	3
Slope	114	212	111	196	91	49.4	54	50	38	31
TOTAL	231	393	219	515	294	100.0	100	100	100	100
SHADY										
Path	125	165	123	299	214	40.2	29	37	44	49
Bank	35	68	23	27	30	11.3	12	7	4	7
Slope	151	336	186	353	191	48.5	59	56	52	44
TOTAL	311	569	332	679	435	100.0	100	100	100	100

(b) Distribution of Dung - gms. ovendry -

Date	SUNNY			SHADY		
	Path	Bank	Slope	Path	Bank	Slope
17.3.66	253.3	4.6	60.0	180.6	1.1	36.6
5.4.66	142.1	-	37.4	109.9	5.0	26.4
29.4.66	143.9	-	17.8	123.4	-	63.7
16.5.66	95.5	8.1	27.4	191.0	-	46.9
1.6.66	133.6	0.9	167.2	82.8	7.6	107.4
17.6.66	171.7	-	41.8	169.2	3.2	22.8
TOTALS	940.1	13.6	261.1	856.9	16.9	303.6
%	77.4	1.1	21.5	72.8	1.4	25.8
% of Area	32	15	53	35	12	53