

The behaviour of Scottish Blackface sheep
and their preferences for different swards,
as observed on a hill pasture in South-East
Scotland.

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by

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SUMMARY

Hill sheep pasture is composed of different types of sward, the grazing sheep having a choice among them. Their degree of preference for the swards, and the manner and cause of its seasonal variation were studied. A review of the literature is given.

The material and methods used in the study are described, the latter involving direct observation of the number of grazing sheep per unit area of sward. Observations were made on 76 days, over a period of 25 consecutive months, 10,060 grazing-sheep-locations being recorded.

In the 76-acre area observed, the following swards occurred:- nardus, molinia, flush grass*, agrostis-fescue, bracken-infested-agrostis, burnt, old, young and lea heather, and draw moss. The sheep showed marked preferences among the swards and the order and degree of these varied seasonally.

The reasons for this, and their long-term effects on the ecology of hill pastures, are discussed.

A review of the literature on animal behaviour, with particular reference to that of sheep, is given.

* As used here the term 'flush grass' refers to an agrostis-fescue sward growing near springs and thus subject to periodic irrigation by water rich in bases.

The diurnal, and seasonal changes in certain aspects of hill sheep behaviour are described and discussed. A note is made on the relationship of hill sheep behaviour to helminthiasis and tick infestation.

INTRODUCTION

The management of hill pastures is characterised by many distinctive features. One of these is that the sheep have a choice among different types of sward.

The degree of preference the sheep have for the different swards, the manner and cause of its seasonal variation, its relation to the management, and its long-term effects on the ecology and vegetation of hill pastures are the subjects of this study.

The degree of preference the sheep have for particular swards, is a measure, although both indirect and inexact, of the grazing value of these swards.

REVIEW OF LITERATURE

There is little data on the yield of hill pasture swards. What there is comes mainly from the workers of the Welsh Plant Breeding Station, and derives from their studies on the improvement of hill pasture.

The figures given in Table 1 are the yields of the control plots used in their experiments. As a reservation, it should be noted that the method of measuring the yield of a sward affects the yield, and that wide differences can occur between pastures of the same botanical composition. Nevertheless, these figures show a clear superiority of agrostis pasture over fescue and of fescue over molinia. To generalise the results, and only wide generalisations are possible, molinia yields 500-1000, fescue around 1,000 and agrostis from 1,000 to 2,000 lb. /D.M./ acre. Under manurial treatment and improved management these figures are completely altered. The values presented here are thought to represent the production of these swards under typical hill sheep farming conditions.

Stapledon & Thomas (1) found the distribution of the yield of upland pasture to be sharply contrasted to that of lowland. It was much later, reaching maximum productivity in July and also producing a smaller proportion of its yield in/

Table 1

Pasture Type	Years averaged for yield figure	Yield	Recalculated Yield D.M./lbs/acre (Air-dried for. 86% D.M.)	Technique	Reference No.	Remarks
Molinia on peat pH = 3.76	3	504 gms. D.M./4 sq.yds.	1341	Cut with sheep shears, plots = 4 sq.yds. 2 cuts season 1931, 3 cuts in 1932 and 1933	4	No grazing
Molinia on peat	1	8.4 cwt (= 100 lbs.) air dried fodder/acre	722	Triplicate plots cut monthly, May 1st - October 30th, with sheep shears.	1	No grazing
Molinia	3	9.9 cwt (= 100 lbs.) air dried fodder/acre	851	Yield = D.M. before less D.M. after grazing	2	Over period of years, grazing increases the yield of the control plots. Yield in first year of experiment used in calculation.
Molinia	2	8.5 cwt (= 100 lbs.) air dried fodder/acre	731	One 6'x6' plot cut with sheep shears monthly 1st May-October. Winter growth allowed to accumulate.	3	No grazing
Festuca	2	9.0 cwt " " "	774	As already given for this reference	1	
Festuca	1	11.2 cwt " " "	963	" " " " " "	3	
Festuca-agrostis	3	20.3 cwt " " "	1745	" " " " " "	2	The high yield in this case is due, in the author's opinion, to the effect of grazing
Festuca-agrostis	3	20.8 cwt " " "	1789	" " " " " "	2	" " " " "
Agrostis-fescue	2	13.2 cwt " " "	1135	" " " " " "	1	
Agrostis	2	16.5 cwt " " "	1419	" " " " " "	1	

winter. Milton (2) states that both fescue-agrostis and molinia pasture gave 50% of their May-September yield in July-August and only 31% in May-June. The winter yield (November-April), as a percentage of the total, was below 12% in all cases. Davies and Jones (3) write that the upland fescue-agrostis pasture made "really active growth only during May-June-July" while winter growth (November-April) was 5% of the total growth.

The rate of protein production reaches its maximum late in summer. Gregor, Watson & Connel (5) give the following results:-

Rate of growth in terms of relative yield of crude protein at four sampling dates (fescue-agrostis pasture)

(adapted from Gregor, Watson & Connel)

15th April	5th June	20th July	27th August
58	89	100	72

No data for the yield of other types of graminaceous hill pasture are known.

The yield of heather is examined by Thomas & Dougall (18), but the data they give for the yield of heather of different ages cannot be recalculated to give a figure for annual production. In assessing the yield of edible material from heather a problem arises. The manner in which the sheep graze the plant is not yet clear, and the/

sampling of heather, to imitate selective sheep grazing, has become almost a study in itself (6 & 7).

Air-dried edible material varied from 3,542 lb. /acre for heather three years after burning, to 4,193 lb. /acre nine years after burning (8), the rate of annual production (= the ratio edible material: gross weight) being highest three years after burning. Thomas and Dougall give the following table on the yield of crude protein etc.

Yield of crude protein etc., in lb. / acre

Interval since burning	3 yrs.	5 yrs.	7 yrs.	9 yrs.
Crude protein	238.9	231.7	357.2	310.1
P205	10.7	9.4	12.9	10.6
CaO	20.5	22.1	26.7	25.1

A number of workers have chemically analysed certain hill plants. The principal worker, and publisher of the most recent papers is Thomas. He reviews the work of earlier workers on the chemical composition of hill plants - Kinch (9), Fagan (10), and Lauder & Comrie (11), and also discusses the observations on the grazing value of particular hill plants made by Stapledon (12), Linton (13), and Wallace (14). The literature on heather has been reviewed by Lamont (18).

Much of Thomas's work has dealt with heather, and it is to him we owe most of our knowledge of the grazing value of the plant. In a series of papers (15, 16, 17, and 8) he has dealt with the /

effects of age and season on its yield and chemical composition.

The value of heather declines with age - nitrogen, silica-free ash, CaO and P2O5 decreasing while the ether extract increases. The low mineral content is offset by the fact that heather is rich in iron, manganese, copper and cobalt. Copper and cobalt deficiency in sheep give rise to sway-back and pining respectively; iron deficiency results in anaemia while the significance of manganese in the nutrition of the sheep is not yet fully understood. The nutritional value of the mineral content of heather is therefore obvious. The value of heather is at its highest during the early summer, at which time the crude protein approaches 10% of the D.M., and is at its lowest during the winter. As the heather ages the summer: winter variation in chemical composition becomes very small. Thomas concludes that heather, judged on its D.M. production, on its value as a winter food, and as a source of minerals, is a valuable plant on hill grazings.

In addition to the work on heather, Thomas and his associates have published chemical analyses and observations on the grazing value of molinia (19), draw moss (20), blaeberry (21), stool bent (22) and a paper on the ash components /

of molinia, deer hair, blaeberry, white bent and stool bent (23).

Molinia has by 26th April a high protein content reaching 19.26% crude protein in the D.M. (30) but, in the present writer's experience, it is the middle of May before much growth is made. When it flowers in late July or early August the feeding value declines sharply and after August it suffers another sharp decline. At its best molinia is comparable to any other grass, but its period of high value lasts for only three months. The calcium content is low, according to Thomas, a finding confirmed by the analyses of Evans (25) and Davies (26). The grass, being deciduous, is useless in winter, a very strong argument against its being of value on the hill.

Draw moss is shown to have a high nitrogen content as early as the 5th of April (11.79% crude protein in the D.M. of the scallion), this, and its high phosphorus content, is the reason for the plant's value in early spring. (20) Thomas suggests that on heather moors draw moss is nutritionally complementary to the phosphorus-deficient heather.

On the value of blaeberry the opinion of the various authorities is at variance, some questioning if the plant is eaten by sheep. Tribe (24) records /

it as being eaten, and the writer noted that it was eaten during snow periods, when the plant, breaking through the snow cover, was readily available.

Thomas's chemical analysis points to its having a substantial feeding value at all times of the year.

A high phosphorus content gives it a qualitative value, while it also contains a substantial proportion of calcium, as do the other Ericaceae found on the hill. The Gramineae found on the hill tend to be deficient in this mineral.

Stool bent, while having no specific qualitative value, is assessed by Thomas as follows:

"As a quantitative supplement at opportune times and under clearly defined circumstances e.g. on white land pasture during winter and on heather moors after burning, stool bent is of considerable value to the hill farmer."

Deer hair has its highest feeding value in the early spring and may be a substitute for draw moss (27). Between April and September the value declines. The plant is not greatly favoured by sheep, though Tribe records it as being eaten (24).

In nardus both the calcium and copper content are low while the silica content is high, a fact which is perhaps related to the unpalatability of the grass. Thomas suggests that in pining areas, (his analytical sample was from an area not affected /

by pining) the cobalt content may also be low, and the low mineral content of nardus may thus account for the prevalence of pining in white land areas.

Fagan & Watkins (10) have published chemical analyses of herbs not dealt with by Thomas. Included in their analyses are typical hill pasture species such as yarrow, wood rush, wild pansy, Potentilla erecta, Veronica officinalis, sorrel, self heal, Carex spp., Juncus communis, ragwort, Plantago lanceolata, Erica tetralix, gorse, daisy, Ranunculus repens, Hypochaeris radicata and bog asphodel. Except for wood rush and deer hair, the analyses were done on samples taken on one date only. In general they find the herbs, and in particular their leaves, to be rich in crude protein and minerals.

The mineral status of hill pastures has been studied by Elliot et al. (23). Hill vegetation was found to be poorer in silica-free ash while the calorific value was almost identical and the nitrogen content slightly inferior. The writers note that sheep, where they have a choice, graze the species which are richest in minerals. It is no doubt true, that the species not favoured by sheep have a poorer mineral content than those favoured, but it is almost impossible to measure the degree of inferiority. To do so, the analytical sample would have to be truly representative of the /

sheep's diet, and it is the nature of this diet which was, and remains, a problem.

The work of Orr and Frazer (29) has shown that on one hill pasture, and presumably on many, where lambing and live weight increases were poor, it is not mineral deficiency but simply starvation that is the cause. Indeed, most hill sheep lose weight in the period November-May because of starvation, and begin to regain weight from May onwards. (30).

Perhaps the greatest need in hill sheep farming research is for the study of the relationship between pasture type and animal performance. The very nature of hill grazing makes this a difficult task and it is due to Peart's use of a naturally occurring "experimental design" that we have the only published comparison between live weight increases in lambs on heather and grass swards. (31). Peart found that heather gave a significantly greater daily live weight gain between lambing, (8th April-15th May) and 4th June. The position was reversed in the period 4th June to 4th July and subsequent to 4th July the difference between live weight gains was no longer significant. At the final weighing on 28th August the lambs on heather and grass showed an average gain in weight of 61.47lb. and 61.97lb. respectively, the difference being insignificant. Peart gives no data on the change in weight of the ewes. The live weight increase /

of the lambs represents a gain per acre of 73.76 lb. for heather and 74.36 lb. for grass in the period from lambing until 28th August.

The difficulties of conducting experiments to relate hill pasture swards to animal performance has forced at least one investigator to approach the problem in an indirect manner. Boulet (32) based his work on the fact that there is a high correlation between the palatability and nutritional value of pasture. He observed, over a period of 15 months, on pastures where the sheep had a choice among different swards, the number of sheep per unit area of sward. He then calculated comparative grazing intensities, (the ratio between number of grazing sheep and unit area of sward) which are presumed to reflect the value of the sward. Boulet makes the point that, as different swards are either over- or under-grazed, there is therefore no direct relationship between comparative grazing intensity and productivity. The following table is taken from his thesis.

Comparative grazing intensity of different hill pasture swards

<u>Pasture Type</u>	<u>Comparative grazing intensity</u>
Drained Temp. Ley.	100
Agrostis	48
Festuca	33
Undrained Temp. Ley	27
Festuca (grazed)-heather	28
Festuca-Nardus	18
Agrostis-Nardus-Molinia	18
Festuca-fern	14
Nardus-Molinia	17
Wet Molinia	7
Tall Heather	5

If we ignore the drained temporary ley, as not being quite typical of hill pastures, agrostis is then the best type, with festuca and festuca (grazed)-heather second equal. Boulet's classification "festuca (grazed)-heather" is probably what we in Scotland call "lea heather." With the entrance of nardus or molinia there is a sharp decline in comparative grazing intensity as there is when festuca is invaded by fern (bracken). Wet molinia (molinia bog?) and tall heather are the inferior types with a very much lower comparative grazing intensity than agrostis and festuca. Boulet noted a wide variation in the comparative grazing intensity on different areas of heather. This was also noted in the present study.

Boulet does not discuss in great detail seasonal changes in the comparative grazing intensity of different swards, but he remarks that, "Festuca, Nardus and tall heather were grazed more during the winter" and also, "Molinia would be of special value in July and August, cotton grass in February and March, and the fern area (i.e. the grass sward formed under the fern cover) more grazed from October onwards, wet molinia and tall heather in February and March and the night camping area from October onwards."

Each of the pastures studied by Boulet contained one sward which had a much higher comparative grazing intensity than all the others. This was either a temporary ley or an agrostis sward. The relation between these superior swards, and the other swards on the pastures, is broadly similar in all cases.

At some time in the period March-May the comparative grazing intensity on the superior swards is markedly greater than on the other swards, and it gradually declines throughout the year until it reaches its lowest value in the period January-February. This is followed by a very steep increase to the peak values of the period March-May.

Though there are very great differences among the comparative grazing intensities of the inferior swards, they are, in sum, complementary to the variation in comparative grazing intensity found on the superior sward. Low in the period March-May, they gradually increase to a maximum in the months of January-February.

The present writer's explanation of this process is as follows. At the beginning of March the available grazing is at a minimum, and the sheep concentrate on those swards where growth is beginning; this is on the superior swards. As the season advances, and other growth becomes /

available, e.g. on heather and molinia swards, the sheep are attracted away from the superior sward, and its comparative grazing intensity declines. In the months January-February the scarcity of grazing forces the sheep to search all the swards for foggage or any green bite. At this period the comparative grazing intensity on the inferior swards increases. With the beginning of spring growth the process is repeated.

Stapledon (12) arranges the major hill species (omitting heather) in the following order of grazing value.

- grass - Agrostis (various species)
- grass - Sheep's Fescue
- non-grass - Cotton Grass
- grass - Molinia
- non-grass - Heath Rush (because winter green)
- non-grass - Deer Hair
- grass - Nardus

He puts agrostis and sheep's fescue in the same order as does Boulet, and he places a high value on cotton grass. Both Boulet and Stapledon judge nardus to have the least grazing value, Stapledon placing it below deer hair.

Tribe, (24) by close observation of the grazing sheep, determined that they graze heather, draw moss, deer hair, blaeberry, stool bent, molinia, nardus, sweet vernal grass, and Deschampsia caespitosa.

In winter, heather, blaeberry and Deschampsia caespitosa were grazed, and stool bent when the ground was free of snow. Draw moss came into use in January and February. In late spring and summer the fescues were favoured. Nardus was grazed from April until August or September. This summer use of nardus is an exceptional observation, as all other writers found it to be a grass whose use was restricted to early spring.

Tribe notes that the diet of the sheep will be affected by the location of grazing. When the sheep are on the high ground their diet will be restricted to those plants which occur on the high ground, and a similar restriction takes place when they are on the low ground. The location of grazing is determined by the weather. Tribe did not note a seasonal change in the location of grazing (vide infra).

His findings on the behaviour of the sheep tally very closely with those of Boulet (32). The sheep graze the coarser types of vegetation at either end of the day and the finer types in the middle. The coarser vegetation is grazed to a greater extent when it is wet with dew or rain.

Milton (33) has studied the palatability of hill plants by comparing the relative amounts eaten with the relative amounts present in a hill pasture. He assessed their palatability in two /

periods of the year, the winter period (October - March) and the summer period (April-September).

All the plants were grazed, to some extent, in the winter, while at the same time there were great differences in palatability. Those plants, which were relatively unpalatable in winter, were of greater unpalatability in summer. This, Milton concludes, is due to the greater availability of food in the summer allowing the sheep to exercise greater selectivity, and corresponds to Boulet's findings on seasonal changes in the comparative grazing intensity.

The species he studied fall into the following order of palatability in the winter and summer periods. The table is adapted from Milton.

Order of Palatability

<u>Species</u>	<u>winter period</u>	<u>summer period</u>
<u>Anthoxanthum odoratum</u>	1	1
<u>Triodia decumbens</u>	2	2
<u>Agrostis spp.</u>	3	8
<u>Festuca spp.</u>	4	9
<u>Carex spp.</u>	5	3
<u>Juncus squarrosus</u>	6	4
<u>Luzula campestris</u>	7	7
<u>Vaccinium myrtillus</u>	8	13
<u>Nardus stricta</u>	9	10
<u>Galium saxatile</u>	10	11
<u>Potentilla erecta</u>	11	12
<u>Luzula maxima</u>	12	--
<u>Calluna and Erica spp.</u>	13	14
<u>Molinia caerulea</u>	--	6
<u>Scirpus caespitosus</u>	--	5

The major change between the winter and summer periods is the displacement of Agrostis and Festuca /

spp. from 3rd and 4th place to 8th and 9th. Carex spp. maintain their high winter palatability and move from 5th to 3rd place while Juncus squarrosus moves from 6th to 4th place.

Milton's results indicate that the better species, e.g. Agrostis and Festuca spp., are grazed more intensively in winter. He found that heather, of very low palatability in winter, was not grazed in summer, a rather unusual observation.

Our understanding of many of the problems of hill pastures is almost negligible. In the fields of pasture improvement, the ecology of hill vegetation, and the chemical composition of hill plants, considerable work has been done. But we know exceedingly little about the relation between hill pasture conditions and the performance of hill sheep, or about the manner in which sheep "work" their ground.

A knowledge of the chemical composition of a species is of limited value when we do not know at what season, and to what extent, the sheep eat it.

A partial answer to this last problem can be got from a study of the behaviour of the sheep towards the various types of hill pasture sward. Such a study should determine at what season of the year they are grazed by the sheep and what degree of preference the sheep exercise among them. This was the essence of Boulet's study as it is of this.

MATERIAL and METHOD

Various methods have been used to determine the qualitative composition of the hill sheep's diet.

Tribe, using binoculars, approached as near as possible to the grazing sheep, and having noted the plant which had been grazed, went forward and identified it.

Milton, from the appearance of the plant, estimated if it had been grazed (33).

Other workers have studied, and are studying, the qualitative composition of the diet by identifying the plant remains in the rumen and faeces (34 & 35). This last method may prove satisfactory in determining the qualitative composition of the diet, but its use in the determination of the quantitative composition appears unlikely, as so far it has proved impossible to relate rumen analyses to a diet of known quantitative composition (36).

These methods are used in determining the species eaten by hill sheep. An alternative approach, that used by Boulet, ignores the determination of the particular species eaten and studies the preferences of the sheep for different plant communities or swards. The preferences of the sheep for the different swards are measured by the comparative densities of grazing sheep on a unit area of them. While swards do not have the /

degree of individuality possessed by species, they are, nevertheless, clearly defined units of vegetation, not merely convenient artificial classifications, and are valid objects of study.

A hill pasture suitable for this observational work has to satisfy the following conditions. It should contain a number of sward types and the areas they occupy should be sharply demarcated. There should be very little "dead ground" and the pasture should be over-looked by a high vantage point lying in close proximity.

A suitable pasture was found at Overshiels Farm, Fountainhall, Midlothian, belonging to Lord Whitburgh. (See Ordnance Survey, 1908, Edinburghshire, Sheet XXIII, S.W.) Map No. 1 shows the area observed, the site of the observation hut, and the vegetation of the area. Because of the lie of the land, and the difficulties encountered in observation on the many days of mist and rain, the observed area was restricted to approximately 76 acres. This area of 76 acres forms part of that grazed by a four-score heft of Scottish Blackface sheep, a bound heft of breeding ewes in regular ages, called the Middle Cut. The area grazed by the heft is also drawn.

It will be noted that the observed area is only part of the area grazed by the heft. In practice this meant that on some days all 80 sheep /

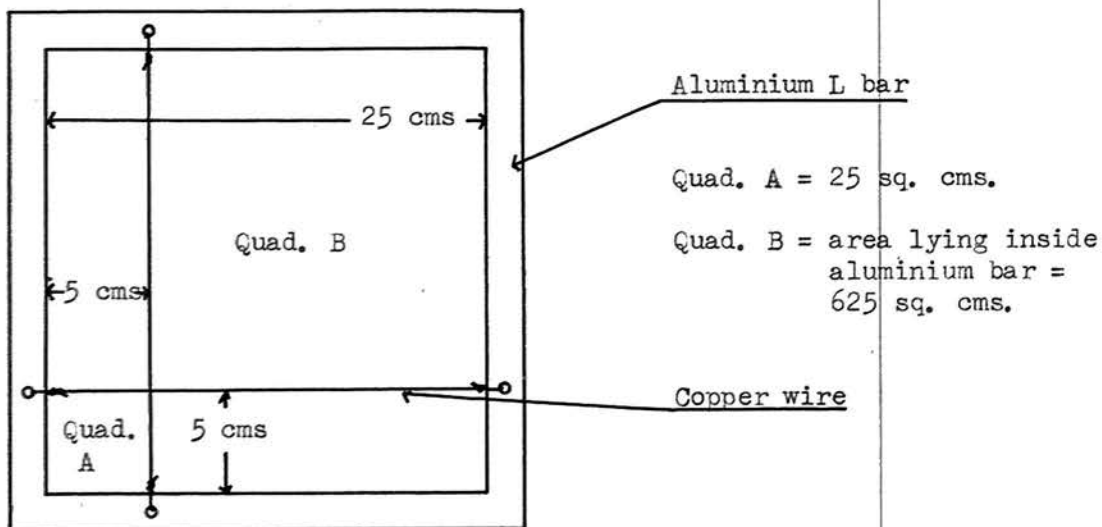
would be in the observed area; on other days the numbers would be fewer or perhaps there would be none.

The vegetation map of the area grazed by the Middle Gut was compiled from direct observation and by the use of aerial photographs.

For the vegetation of the observed area see Map No. 2. This is inserted loose at the back of the volume to allow the reader to place it in front of him and refer to it while reading the text.

BOTANICAL ANALYSIS

The specific frequency method (37) was used in the analysis of the swards. The design of the quadrat used is illustrated below.



From data presented by another writer, 25 sq. cms. and 625 sq. cms. appear to be suitable quadrat sizes for use in the analysis of grass and heather swards respectively (38). The quadrat was thrown 20 times at random in each area of sward analysed. These areas are shown in map No. 4. On the grass swards two records were made at each throw, the occurrence of species in quadrats A and B. If a species occurs in quadrat A it naturally occurs in quadrat B. A species was said to occur when any part of it lay within the area of the quadrat. In the analysis of the heather swards a record was made only of the species occurring /

in quadrat B.

This method of analysis does not indicate the ground-cover afforded by any species nor its contribution to the D.M. yield of the sward. It is not therefore a grazier's analysis, or evaluation, of a sward, and in the description of grazing characteristics has to be used with discretion. An example of this is the occurrence of molinia in molinia bog and in heather. In the first case molinia is the dominant species in the sward, in the second case it is not dominant but occurs as an even dispersion of a few molinia shoots. In both cases, however, its frequency is 100%.

Presentation of data

Any species could occur 1-20 times in the analysis of an area. The actual scores were grouped in the following classes.

<u>Frequency class</u>	<u>Score</u>
T*	occurs in large quadrat only
1	1-4
2	5-8
3	9-12
4	13-16
5	17-20

*In the analysis of the grass swards a species which occurred only in the large quadrat, quadrat B, was placed in the trace class. The trace class does not appear in the analysis of the heather areas.

Trace species help to define the community botanically, but do not greatly influence the grazing value of a sward.

In reading the data it should be remembered that the relationship between frequency and abundance is logarithmic and not arithmetic, and therefore the increase in abundance of a species is not represented by an arithmetic progression from frequency class 1-5 (39).

Recording the Location of the Grazing Sheep

Map No. 1 shows the site of the observation hut, and drawing No. 1 the instrument used in recording the location of the grazing sheep.

The instrument, made of angled brass rod, was placed on a plane table inside the hut so that the arm A projected a few inches outside the hut and the axis C lay in line with the wall of the hut. The instrument could be rotated in a horizontal plane about the axis C and was used in the following manner.

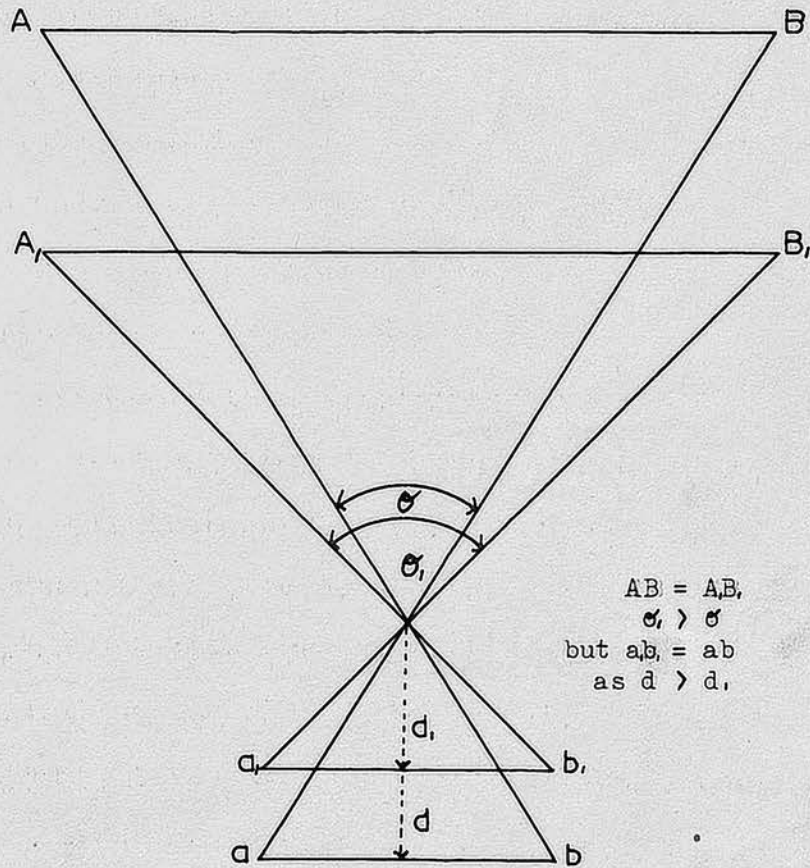
Looking through the eyepiece, a small hole bored in the arm B, the pointer mounted on the slide G was brought to bear on a sheep, by moving slide D backwards or forwards. Slides D and G were connected by a length of twine passing over pulleys at E and F. When the sheep was correctly aligned, the plunger on slide D was pressed and its pinpoint made a hole in a sheet of paper laid on the cork covering of the plane table.

This pinpoint was a permanent record of the location of a grazing sheep at a particular time, and the method enabled the location of 80 grazing sheep to be recorded in five minutes.

Readings were taken at hourly intervals using a fresh sheet of paper for each recording. It remained to ensure that separate hourly readings could be related to each other. Before each /

reading, slide D was brought into a fixed position by a screw passing through the slide and mating with a screw hole on arm H. The pointer was then aligned on a landmark by turning the adjusting screw. This location, and that of two other landmarks, were then pinpointed on the paper. Each sheet of paper bore these three pinpoints and each sheet could be correctly orientated towards the others, and to a map of the area, by superimposing these pinpoints.

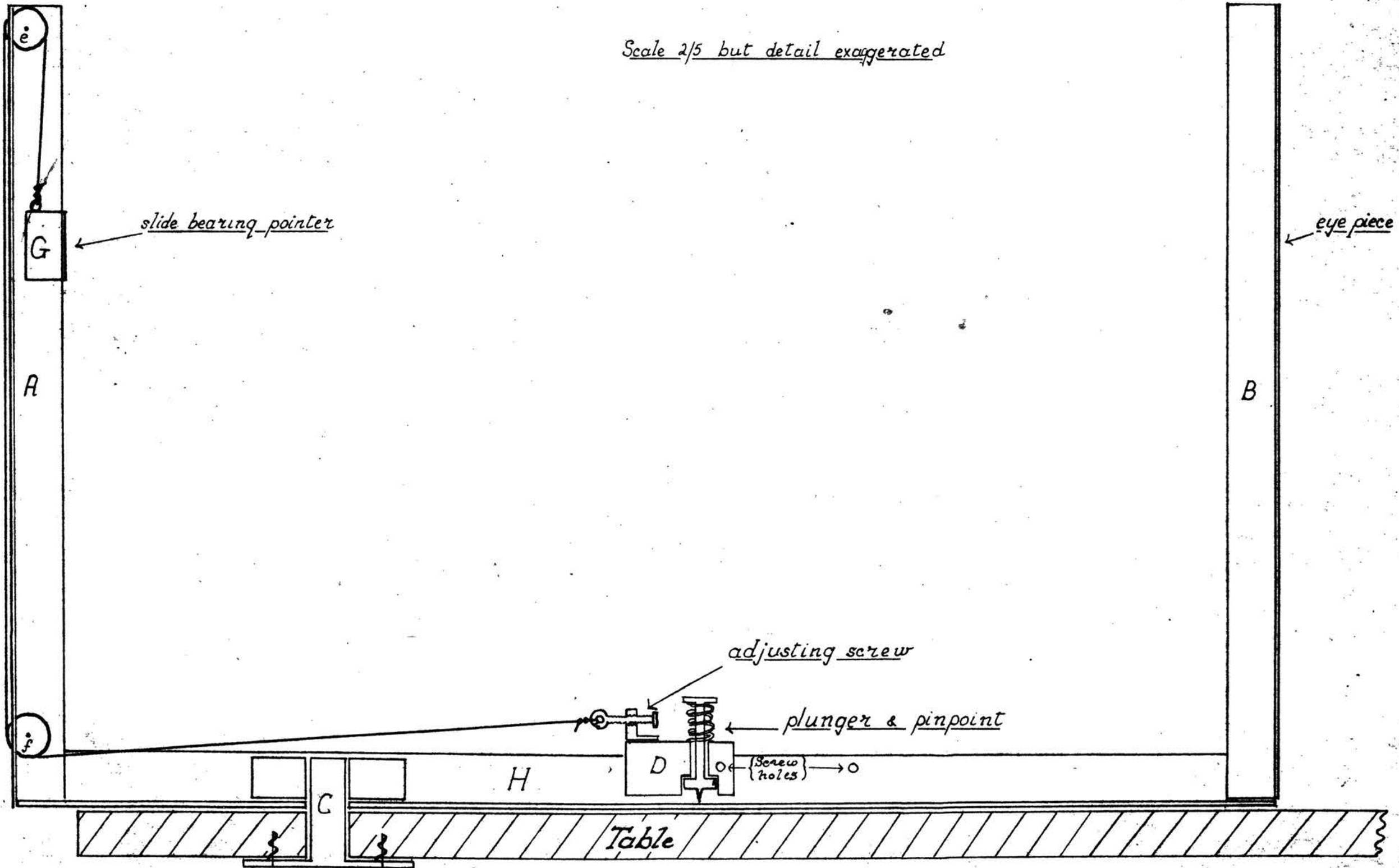
It is obvious that the accuracy of the instrument is related to the distance of an object from the observation hut, as objects of the same size subtend smaller angles at a fixed point, with increasing distance from it. The accuracy of the instrument is, however, increased by the lie of the ground. As objects get farther away they also, moving up the hill, gain in height, and to align them slide D has to be moved farther away from the axis C. Thus a diminution in the angle subtended by the horizontal dimensions of the object has been offset by an increase in its projection. The argument is illustrated below. (see over).



No such compensation takes place with the vertical dimensions of an object.

Drawing No. I.
Instrument for recording location of sheep

Scale 2/5 but detail exaggerated



Accuracy of recordings

If a fixed object was repeatedly pinpointed with the instrument the pinpoints generally coincided but a maximum error of 1 mm. could arise. This was due to changes in the tension of the twine affecting its length and, when visibility was poor, to the difficulty in aligning the object.

The maximum error of 1 mm. will give rise to an error in correctly recording the location of grazing sheep, at various distances from the observation hut, given in the table below.

Distance from the observation hut in direction of the round stall/feet	Horizontal error/feet	Vertical error/feet
1340	3'8"	7'2"
1830	4'4"	9'2"
2326	5'0"	14'0"
2820	5'8"	20'0"

As the areas of the swards extend hundreds of feet in length and breadth, and the maximum error is infrequent, the chances of a false grazing-sheep-location record being made are small.

Making the vegetation map and recording the location of grazing sheep

The observed area was squared into squares of 100 feet side and turves dug at the corners of each square. For this purpose a datum line, running from the east end of the round stall to the observation hut, was used. As each turf was dug, its location was signalled, and recorded with the instrument on a sheet of Ethulon, a transparent plastic film.

Accuracy of recordings

If a fixed object was repeatedly pinpointed with the instrument the pinpoints generally coincided but a maximum error of 1 mm. could arise. This was due to changes in the tension of the twine affecting its length and, when visibility was poor, to the difficulty in aligning the object.

The maximum error of 1 mm. will give rise to an error in correctly recording the location of grazing sheep, at various distances from the observation hut, given in the table below.

Distance from the observation hut in direction of the round stell/feet	Horizontal error/feet	Vertical error/feet
1340	3'8"	7'2"
1830	4'4"	9'2"
2326	5'0"	14'0"
2820	5'6"	20'0"

As the areas of the swards extend hundreds of feet in length and breadth, and the maximum error is infrequent, the chances of a false grazing-sheep-location record being made are small.

Making the vegetation map and recording the location of grazing sheep

The observed area was squared into squares of 100 feet side and turves dug at the corners of each square. For this purpose a datum line, running from the east end of the round stell to the observation hut, was used. As each turf was dug, its location was signalled, and recorded with the instrument on a sheet of Ethulon, a transparent plastic film.

When the observer had become acquainted with the ground, and the swards in autumn were clearly defined by their colour differences, their outlines were traced on the sheet of Ethulon with the instrument. This gave a "picture" of the vegetation of the area, and of the 100 feet grid covering it; the lines of the grid and the outlines of the swards being traced with indian ink.

The "picture" was of course distorted, but a map on a plane projection could readily be made from it using as co-ordinates the 100 feet grid. With a planimeter, the approximate areas of the swards could be found from the plane map, and by calculation, their proportion of the observed area. To check the accuracy of the vegetation map, aerial photographs and direct measurement on the ground, were used.

The position of the three landmarks was recorded on the Ethulon sheet. This was then placed over a paper sheet carrying a record of grazing-sheep-locations, the landmark pinpoints on both sheets being made to coincide.

Through the outlines of the swards, traced on the Ethulon sheet, the location of the grazing sheep could be seen at a glance. All that remained to do was to note the type of sward, count the number of sheep on each, and record the time and date of the observation.

DATA

Observations were made over a period of 25 months, from September 1950 to September 1952 inclusive. Records of grazing-sheep-location were taken at hourly intervals from dawn to dusk on 76 days, a total of 726 hours 25 minutes observation being made, (see table 2) and a total of 10,060 grazing-sheep-locations being recorded.

Reduction of data and the manner of its use

The number of sheep recorded at hourly intervals on each area of the swards was counted for each month. These numbers, and the total on each sward type, were then calculated as a percentage of the total recorded in the month. The total area of each sward type, and its separate parts, were calculated as a percentage of the total observed area. The following values were then calculated.

The monthly comparative grazing intensity (c.g.i.)

This was got from the calculation:-

100 X percentage of sheep on the sward type
or a part of the sward type ÷ percentage of the
total observed area occupied by the sward in
question or by a part of it. Thus, if 10% of the
total sheep recorded in May, were recorded as
grazing sward A, which occupied 10% of the total
observed area, then the monthly c.g.i. in May =

$$100 \times \frac{10}{10} = 100.$$

Table 2

Number of Days' and Hours' Observation in each Month
during the Period September 1950 to September 1952

	1950		1951		1952		Total	
	Days	Hrs. mins.	Days	Hrs. mins.	Days	Hrs. mins.	Days	Hrs. mins.
January	-	-	1	5 30	3	14 0	4	19 30
February	-	-	2	7 0	6	47 0	8	54 0
March	-	-	4	29 10	4	31 15	8	60 25
April	-	-	1	10 0	4	49 25	5	59 25
May	-	-	4	56 0	2	27 0	6	83 0
June	-	-	2	30 40	2	25 0	4	55 40
July	-	-	3	43 0	4	46 40	7	89 40
August	-	-	4	45 15	4	50 20	8	95 35
September	2	22 0	3	32 5	3	30 0	8	84 5
October	3	24 30	3	25 0	-	-	6	49 30
November	3	24 0	4	29 45	-	-	7	53 45
December	3	10 0	2	11 50	-	-	5	21 50

Total hours' observation = 726 hours 25 minutes

Total days' observation = 76

Total number of grazing-
sheep locations recorded
in period = 10,060

The average monthly comparative grazing intensity

This was calculated from the sum of the numbers of sheep recorded in the same month in different years.

Average comparative grazing intensity

This is the mean of the average monthly c.g.i.-s of different sward types in the period October 1950 to September 1952. The value for the September 1950 c.g.i. was omitted from this calculation to avoid weighting the results towards the September values.

The use of the data

To show a seasonal change in the c.g.i. on the swards, it was necessary to extend observations over a period of at least two years. The demonstration of this seasonal variation in the c.g.i. will be based on the values of the monthly c.g.i., in the periods, September 1950-September 1951 inclusive and September 1951-September 1952 inclusive.

The description of the seasonal variation in the c.g.i., characteristic of a sward type, will be based on the values of the average monthly c.g.i. This value will also be used to show varying degrees of utilisation of different areas of the same sward type, and the marked preference of the sheep among the different sward types.

The average c.g.i. will be used to show varying degrees of utilisation among the different areas of the same sward type.

In many of the graphs accompanying the text, a fourth value will be shown, the area grazing intensity. This is the grazing intensity which would occur, over the whole area of the pasture, if the sheep grazed it uniformly. In this situation, the percentage of sheep grazing any area of sward, would be in direct proportion to the percentage of the total area occupied by the sward in question. The calculation, $100 \times$ percentage of sheep grazing the sward \div percentage of the area occupied by the sward would always equal 100.

In the graphs, the position of the monthly and average monthly c.g.i., in relation to the area g.i., will convey an impression of the preferences of the sheep among the swards.

Factors affecting the comparative grazing intensity and its measurement

Before presenting the observations it is necessary to discuss the factors affecting the c.g.i. and its measurement. Some of the points should properly be made after the presentation of the observations as they arise out of them. They are, however, taken here as a necessary preliminary to the subsequent discussion of the seasonal variation in the c.g.i. of the swards.

The c.g.i. of a sward is based on the number of sheep which graze a unit area of that sward and will be a resultant of the factors which make the sheep have a preference for it. These factors are listed below.

- (1) The botanical composition of the sward which determines:
 - (a) its productivity.
 - (b) its palatability.
 - (c) the seasonal availability of grazing.
- (2) The grazing animal by:
 - (a) seasonal changes in the location of grazing.
 - (b) its breed characteristics.
- (3) The location of a particular area of a sward type:
 - (a) in relation to exposure.
 - (b) in relation to other swards.
- (4) The proportions of the sward types present in the grazed area.
- (5) The nature of the sward types present in the grazed area.

The c.g.i. is based on observations made during the hours of daylight and is therefore based on/

a sample of the time spent grazing by the sheep.

Its accuracy will be affected by:

- (a) the period of the day during which observations are made.
- (b) night grazing.

(1) The botanical composition of the sward

This is the most important factor influencing the c.g.i. and it has a number of aspects.

(a) Productivity

Different species of plants differ in productivity and the productivity of individual species is in turn influenced by the soil in which they are growing and the management to which they are subjected. It could be expected that the more productive a sward is, the greater the number of sheep which will graze a unit area of it. Over- or under-grazing, however, distorts any direct relationship between c.g.i. and productivity, as do other features of hill grazings.

(b) Palatability

Under this heading are included the stage of growth, the succulence, and possibly, the flavour of the sward, which affect the sheep's preference for it.

(c) The seasonal availability of grazing

On hill pastures, in winter and early spring, grazing is very scarce, and at that time of year the c.g.i. will not be affected so much by the /

productivity or palatability as by the amount of grazing the sward affords. The presence of winter green plants, and the amount of foggage the swards contain, will be important at this time of year.

(2) The grazing animal

(a) Seasonal changes in the location of grazing
(see Map No. 3)

The heft studied at Overshiels changes the general location of its grazing throughout the year. In the months January-March it tends to stay on the low ground but moves to the high ground when the weather is open. It does not show the regular day-low-ground; night-high-ground movement typical of the period from April-September, but rests at night on the low ground.

At this time of year the sheep are not herded except during periods of impending snow. With the arrival of spring and after lambing they begin to move up the hill in the evening, resting during the night in the general area of the round stell, and moving down on to the observed area in the morning. During this period they are herded but will move without herding and it is difficult to decide if their behaviour is "instinctive" or "learnt" by herding.

In the period October-December the sheep stay high, grazing in the area of the round stell throughout the day but coming on to the upper part /

of the observed area to graze the bracken sward. They are not herded very closely, though during tugging time the shepherd has to ensure that the tugs are on their ground and following their ewes. This does not, however, affect the general grazing location.

There are certain obvious reasons for this behaviour on the part of the sheep. The availability of food in different areas, seasonal climatic and diurnal local climatic changes, the seasonal difference in the physical vigour of the sheep, the limitation of movement when followed by very young lambs, and "instinctive" behaviour are some of the obvious reasons. It has been suggested, by a Russian writer (76), that the seeking of high ground at tugging is a pattern of behaviour "learnt" by the sheep's wild ancestors. The wild sheep left the hot plains of Eurasia in autumn and went into the hills to find both food and cooler temperatures. This period coincided with oestrus. Initially unrelated, the two phenomena became related and domesticated sheep today have a "cold requirement" during oestrus.

Our interest is not the reason for "behaviour patterns" in hill sheep, but their effect on the measurement of c.g.i.'s.

It has been observed that there are differences in the behaviour of breeds of hill sheep (77), the /

Scottish Blackface grazing heather more readily than the Welsh Mountain Sheep. Indeed the writer thinks the development of behaviour studies will lead to the understanding that the "behaviour pattern" is one of the characteristics of a breed.

(3) The location of a particular area of a sward type

(a) In relation to exposure

At lambing time sheep are especially sensitive to exposure. They will avoid an area exposed to cold winds and also one so sited that the sun does not melt "hoar" frost early in the day. They will leave such an area in preference for one unshaded and free of hoar frost.

(b) In relation to other swards

Sheep have a normal "rake" on a hill pasture moving between their night-resting areas and their day-grazing areas. They will occasionally graze inferior swards that lie in their path but do not appear to go "out of their way" to graze such inferior swards. Similarly sheep will spread outwards from their main grazing area, on the superior swards, to graze the contiguous inferior swards, but will not go to graze distant areas of inferior swards.

(4) The proportion of the sward types present in the grazed area.

It is reasonable to suppose, that as the proportion of any sward increases or decreases, /

its c.g.i. will change in consequence. A simple illustration of this is the burning of heather. If only a small proportion of the heather is burnt the sheep concentrate on this area and the c.g.i. is high. If the proportion is greater, and the same number of sheep graze the young heather, then the c.g.i. is lowered.

(5) The nature of the sward types present in the grazed area

If we consider two swards with a marked and broadly similar period of seasonal use, e.g. molinia and young heather, their use will be affected according to whether either or both are present in the area. Where only molinia or young heather is present the sheep will be offered no choice. Where both are present they have a choice and the c.g.i. will be affected by their choice.

(6) The period of the day during which observations are made

Boulet (32) and Tribe (24) have noted that sheep eat the rougher herbage at either end of the day and the finer herbage during the middle period.

As observations can only be made during daylight, and day-length changes throughout the year, it is obvious that the time of observation, during the 24 hours daily period, changes with the season of the year.

This might be thought to influence greatly the /

accuracy of the observations, but, for the following reasons, it is doubtful if this is the case.

(a) There is no similarity between the c.g.i.'s recorded in those spring and autumn months which have the same day-length.

(b) The sheep tend to concentrate their grazing in the hours of daylight. Thus, while the daily period of observation is much shorter in winter than in summer, the difference in the time spent grazing on a winter and summer day, is not so wide.

(7) Night grazing

If the sheep's seasonal preference for different swards during the hours of dark varied independently of their preference during the hours of daylight, this would greatly affect the accuracy of these observations. This is thought to be most unlikely and night grazing therefore not to affect their accuracy.

The c.g.i. on swards is influenced by many factors and will vary between hill pastures. On one hill pasture a sward might have a much higher c.g.i. than all other swards; on another, owing to changes in the proportion and type of swards present, the difference might not be so great. The c.g.i. of a sward is a value therefore which is likely to vary between hill pastures, though not, it is thought, to any great extent.

A characteristic of a sward, which is unlikely to vary in the range of pastures in which it occurs, is the period, or periods, of its utilisation by the sheep. On one pasture heather may have a much higher average c.g.i. than on another. If, however, the monthly or average monthly c.g.i.'s of these two areas of heather are plotted on the same graph their periods of greater or less utilisation will occur in the same period of the year.

It is this characteristic of a sward, its seasonal utilisation, as determined at Overshiels, which is thought to be typical of the sward wherever it occurs.

Meteorological data during the period of observation

This was supplied by the Meteorological Office and was collected at the meteorological station at Loan, Lauder, Midlothian. The station lies eight miles east of Overshiels and at an altitude of 550 feet. It was thus considerably lower than the observed area which lies between 1000 and 1200 feet.

The data shows the considerable differences between the period December-May in 1950-51 and in 1951-52, the former being more severe in every way. Snow lying at 0900 hours was recorded on 52 days in the first and on 30 days in the second period. In only one month, January, was the average of the mean of the max. and min. temperatures greater in the first period. Rainfall was also greater in the first period in every month except December.

Indeed the winter and spring of 1950-51 was a severe one for hill farming generally and this was reflected in low lambing percentages on many farms. Lambing percentages for the Middle Cut were 99% in 1950, 42% in 1951 and 100% in 1952.

RESULTSBracken Sward (29.5% of area)Botanical composition

(See Appendix A, Table 1 and Map No. 4)

The bracken sward is the grass sward formed below a canopy of Pteridium aquilinum and on these areas the density of the canopy was low. Its effect was to suppress certain grass species, alter the type of growth of others, while not being so dense as to cause the development of a sward dominated by Holcus mollis or by Galium hercynicum.

If we consider Agrostis tenuis and Poa pratensis as superior types of hill grasses then the bracken sward had the best botanical composition of the various swards. A. tenuis was dominant and P. pratensis had its highest frequencies in the bracken sward, reaching 4 in areas 5c and 11d. Festuca rubra and ovina, Agrostis canina and Anthoxanthum odoratum were common, while Nardus stricta, Holcus lanatus, H. mollis and Trifolium repens were of low frequency.

In appearance the sward was rather open and was green and succulent in mid-summer and early autumn when it had few flowering culms.

The sward was floristically rich, indicating that the bracken canopy was not dense. 14 analyses were made in the localities numbered on Map No. 4, an average of 23 species per analysis, and a total of 54 species, being recorded.

Comparative grazing intensity.

Comparison between the periods Sept. 1950-Sept. 1951
and Sept. 1951-Sept. 1952.

	Monthly and average monthly c.g.i.		
	Sept. 1950-51	Sept. 1951-52	aver. monthly c.g.i.
Sept.	170	239	200
Oct.	196	236	202
Nov.	261	235	244
Dec.	266 ²²⁶	285	250
Jan.	200	62	123
Feb.	91	130	121
Mar.	164	135	152
Apr.	217	215	215
May	206	147	192
June	158	167	163
July	148	157	155
Aug.	102	140	129
Sept.	239	197	---

These values are plotted in graph No. 1.

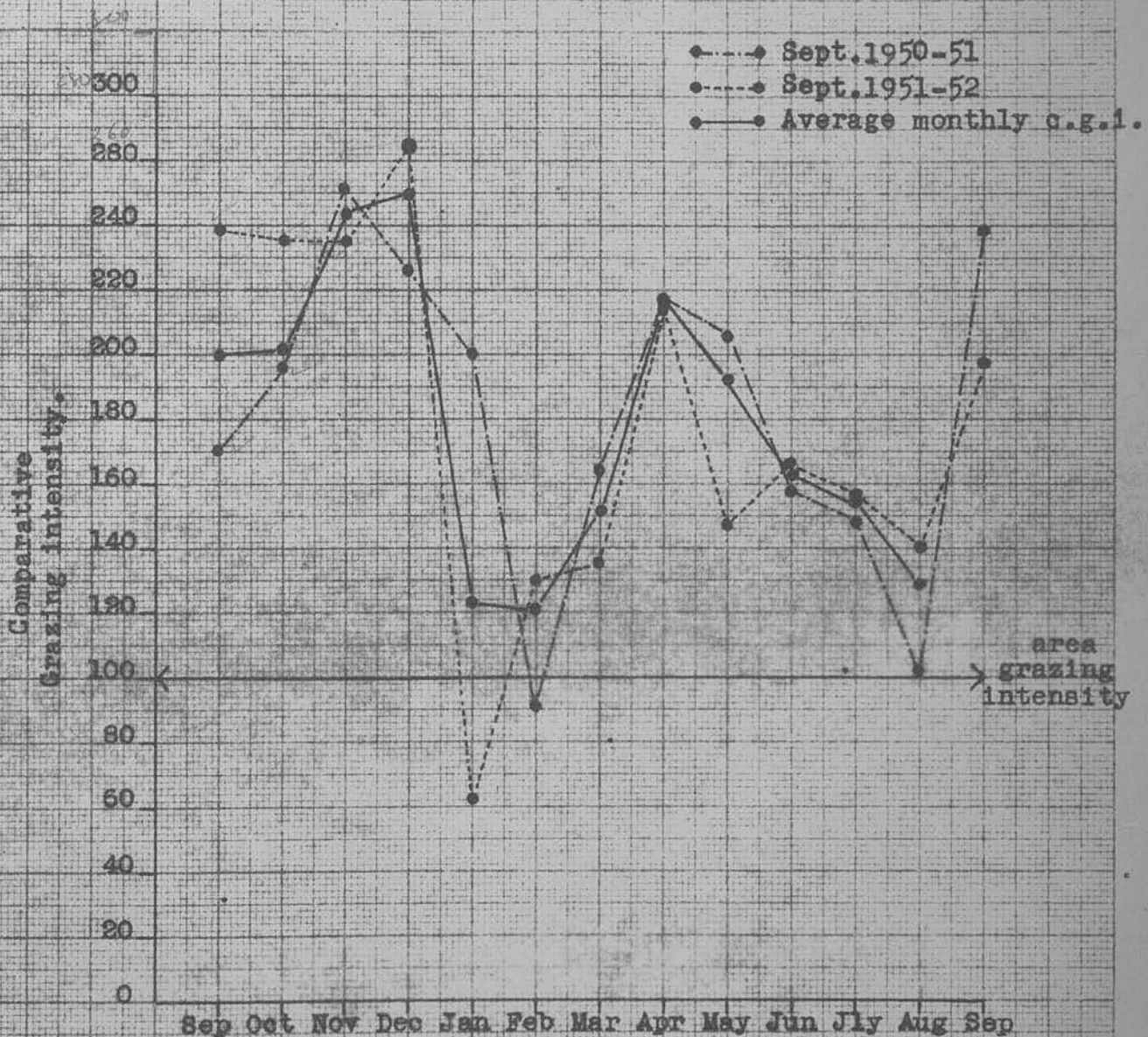
There is a close correspondence in the shape of the curves for the periods September 1950-51 and September 1951-52 which shows the occurrence of a seasonal cycle in the c.g.i.

The average monthly c.g.i. lies at all times above the area g.i. It is at a low value in August and steadily increases in the period September-December to its highest value, then falls in the next month to its lowest values in the period January-February. It then increases to a peak in April from which it steadily declines until August.

As the main bracken sward areas are contiguous to areas grazed at one time or other throughout the year the variation in the c.g.i. cannot be a location effect.

Bracken Sward

Monthly comparative grazing intensity in periods Sept. 1950-51
& Sept. 1951-52, and average monthly comparative grazing intensity.



Comparison of areas of bracken sward.

There are 13 areas of bracken sward but all the important points will emerge in an examination of areas 5, 11, 3 and 8.

Average monthly c.g.i.

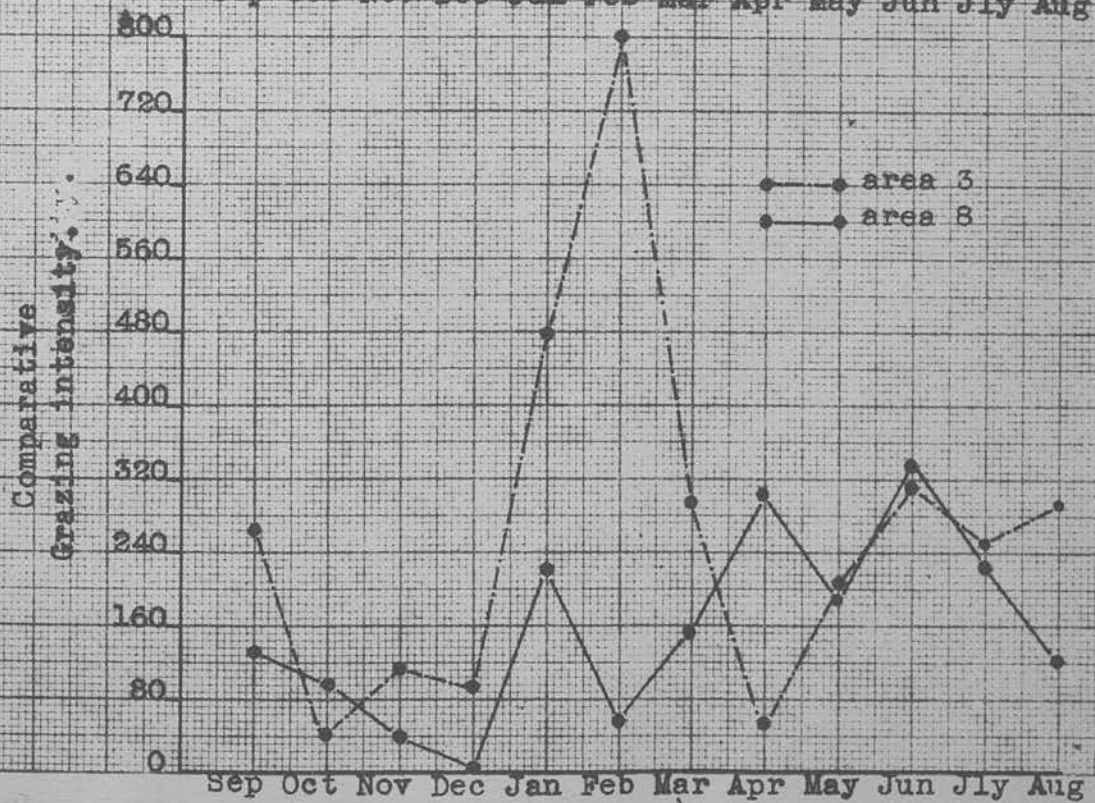
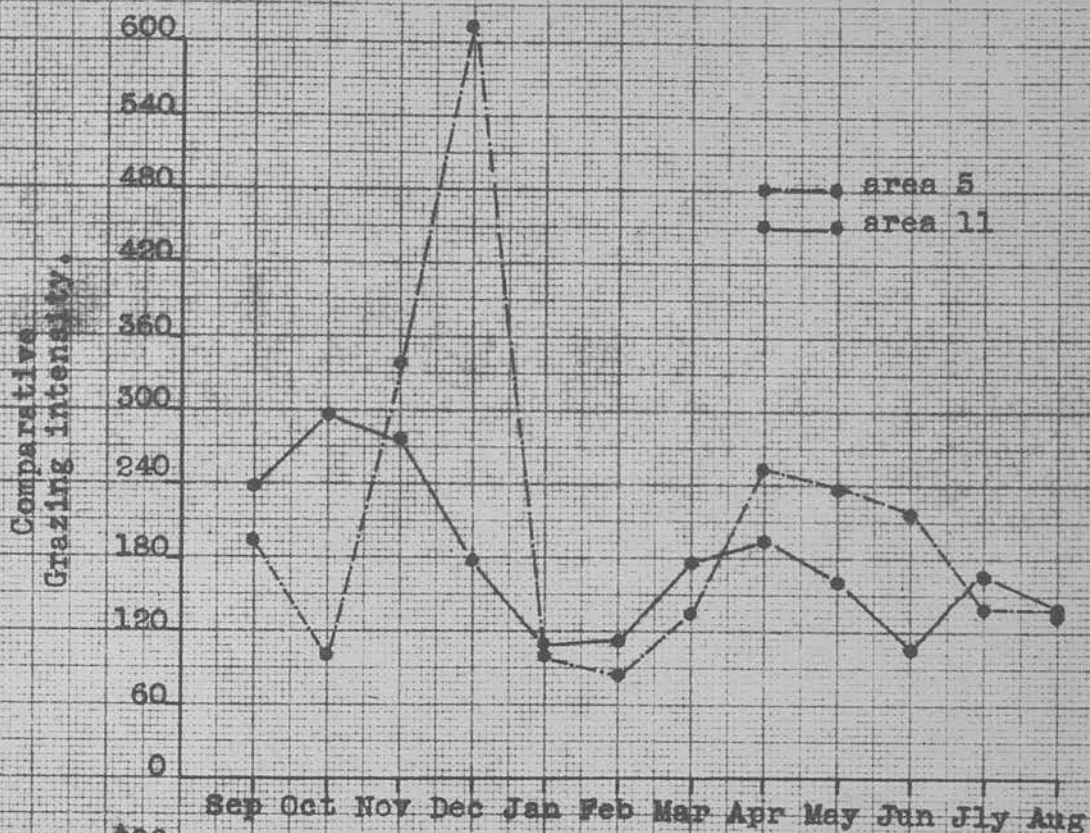
No. of Area	5	11	3	8
%age of total area	7.89	14.28	0.74	2.62
Sept.	195	238	266	133
Oct.	101	296	42	97
Nov.	341	278	117	33
Dec.	613	178	93	-
Jan.	100	110	477	221
Feb.	86	113	801	56
Mar.	133	176	295	155
Apr.	253	193	54	303
May	238	161	208	190
June	217	107	312	335
July	149	167	250	224
Aug.	149	134	294	123

These values are plotted on graph No. 2.

The variation in the c.g.i. on areas 5 and 11, the principal bracken sward areas composing 75% of the total bracken area, is very similar. In December there is a wide difference in magnitude, but what matters, is not the magnitude, but the trend of the values and this does not vary much between the two areas over the year. The very high value for area 5 in December is largely based on the reading for December 1950, a month in which there were few readings, and this small sample has affected the average monthly c.g.i. of the bracken sward in December. It may be that the c.g.i. on bracken sward declines earlier in the year than by the end of December, and probably, in most cases, /

Bracken Sward

Average monthly comparative grazing intensity on areas 5, 11, 3, & 8



it does so by the end of November.

As we should expect in small areas, the variation from month to month in the c.g.i. is high on areas 3 and 8. Nevertheless, the high values for area 3 in the period January-March, and the low values for both areas 3 and 8 in the period October-December are sufficiently marked, and untypical of bracken sward, to deserve comment.

They show the effect the location of an area of a sward type may have on its c.g.i., and to a lesser extent, the effect of the bracken canopy. Both areas 3 and 8 lie on the low ground, an area lightly grazed in the period October-December. The sheep will not move down to the low ground to graze small areas of bracken sward although they graze intensively the areas of bracken sward on the high ground, the general location of grazing at that time of year.

In the period January-March the c.g.i. on area 3 is much higher than on area 8. Area 3 lies between the drains and is contiguous to area 24 which is heavily grazed in winter. The bracken canopy is thin, and both H. lanatus and T. renens have higher frequencies on area 3 than on the bracken sward as a whole. It is therefore not surprising that its seasonal variation in c.g.i. is more typical of ^{*agrostis-fescue*} ~~grass moor~~ than of bracken sward.

Area 8, which has a dense bracken canopy, and, lying on the slope, is drier than area 3, shows no sustained rise in the c.g.i. in the period January-March. In April, and in the following months, it shows the rise typical of bracken sward.

Discussion.

The variation in the c.g.i. arises from the effect of the bracken canopy on the grass below. The initial effect of the canopy is to raise the humidity and depress the light intensity in the ground layer below it (40). Of the two effects, the rise in the humidity is perhaps of greater importance, but together they cause growth, which is, in a varying degree, etiolated, more succulent, and consequently less winter hardy (41). Certain densities of bracken cover may increase the growth of the grass lying below it. Cowlshaw (42) and Williams (43) have shown that a rise in yield takes place in the small areas enclosed by the cages used in grassland experiments, the cages having the same effect as a bracken canopy on wind velocity, temperature and humidity.

A proposed sequence of events to explain the seasonal variation in the c.g.i. of the bracken sward is as follows. When growth begins in spring, the sheep are attracted to the bracken sward, and the c.g.i. increases to a peak in May. As the bracken fronds begin to appear towards the end of /

June, the sheep are attracted away from the bracken sward and to the heather. Under the bracken canopy, neither plant nor soil suffers to the same extent the summer drought which dries out the agrostis-fescue sward, and a quantity of green succulent growth accumulates in the months of July-August. By September, the heather is no longer attractive, the ^{agrostis-fescue sward} grass-moor is stemmy and rank, and when the bracken dies back, about the end of September, the sheep are attracted to the accumulated growth on the bracken sward. Boulet remarks on this concentration of grazing on the bracken sward in the third quarter of the year, and it occurs at Overshiels.

Depending on the relative area of bracken sward in the pasture, and the severity and earliness of frost, the accumulated July-August growth will be exhausted sometime before the end of December. The c.g.i. then falls, in the first quarter of the year, to its lowest values.

The low c.g.i. on bracken sward in the first quarter of the year indicates the deleterious effect a light bracken infestation, in terms of density not extent, has on a hill pasture. In the East of Scotland, where bracken density is generally much lower than in the West, it is sometimes argued that it does not have a serious effect on the pasture, provided the grass sward below it is maintained. /

In so far as a light bracken cover does not greatly, if at all, lower the productivity of a sward, the writer would agree with this. Its deleterious effect on the 'economy' of a hill pasture, in reducing the grazing available in the first quarter of the year, is however disproportionate to any effect it may have on total productivity.

Bracken, at any density greater than a few stunted fronds per sq. yd., causes a deterioration in hill pastures by reducing the winter keep. At higher densities it will cause a reduction in the productivity of the pasture by suppressing the development of a grass sward.

Area 23 and the flush area

(area 23 = 4.2% of area. flush area = 4.9% of area)

Botanical composition (see appendix a, table 11 and Map No. 4)

The flush area is composed of areas 24, 28, 29, 30 and 31. The flush area and area 23 are sometimes grouped together under the title, "agrostis-fescue grassland," and when the comparison is made between grass free and grass not free of bracken infestation, the small area of *Nardus* is also included in the agrostis-fescue grassland.

The main difference between these two areas and the bracken sward lies in *Nardus stricta* and *Holcus lanatus* being co-dominant with *Agrostis tenuis* instead of *A. tenuis* being the single dominant species and in the much reduced frequency /

of Poa pratensis, and greatly increased frequency of Trifolium repens, Ranunculus repens and Carex panicea. Festuca rubra and Festuca ovina are of similar frequencies in both agrostis-fescue grassland and bracken sward, while Anthoxanthum odoratum shows a slight increase in the agrostis-fescue grassland. The frequencies of the principal species common to bracken sward and agrostis-fescue grassland are shown in Appendix A, Table 111.

Area 23 and the flush area are distinguished from each other by the following features. Area 23 is drier and steeper than the flush area, and it is not so closely grazed. N. stricta and Potentilla erecta are more frequent in area 23 and P. pratensis, F. ovina, A. odoratum, Cynosurus cristatus, T. repens and C. panicea more frequent in the flush area. Achillea ptarmica, Taraxacum officinale, J. articulatus, Equisetum palustre and Agrostis stolonifera were recorded in the flush area but not in area 23.

Occurring in the flush area are small areas of Juncetum, areas 28, 29, 30 and 31. The Juncus spp. (principally J. communis agg.), while very frequent in those areas, have not suppressed the development of a grass turf.

Although nardus is very frequent in both areas they are not typical Nardeta. The tussock formation is poorly developed, the areas do not show the "white land" appearance typical of Nardetum in /

autumn and they are floristically rich, which Nardetum is not.

42 species were recorded in the 5 analyses, an average of 25 species per analysis.

Comparative Grazing Intensity

Comparison between period Sept. 1950-Sept. 1951 and Sept. 1951-Sept. 1952.

Monthly and Average Monthly c.g.i.

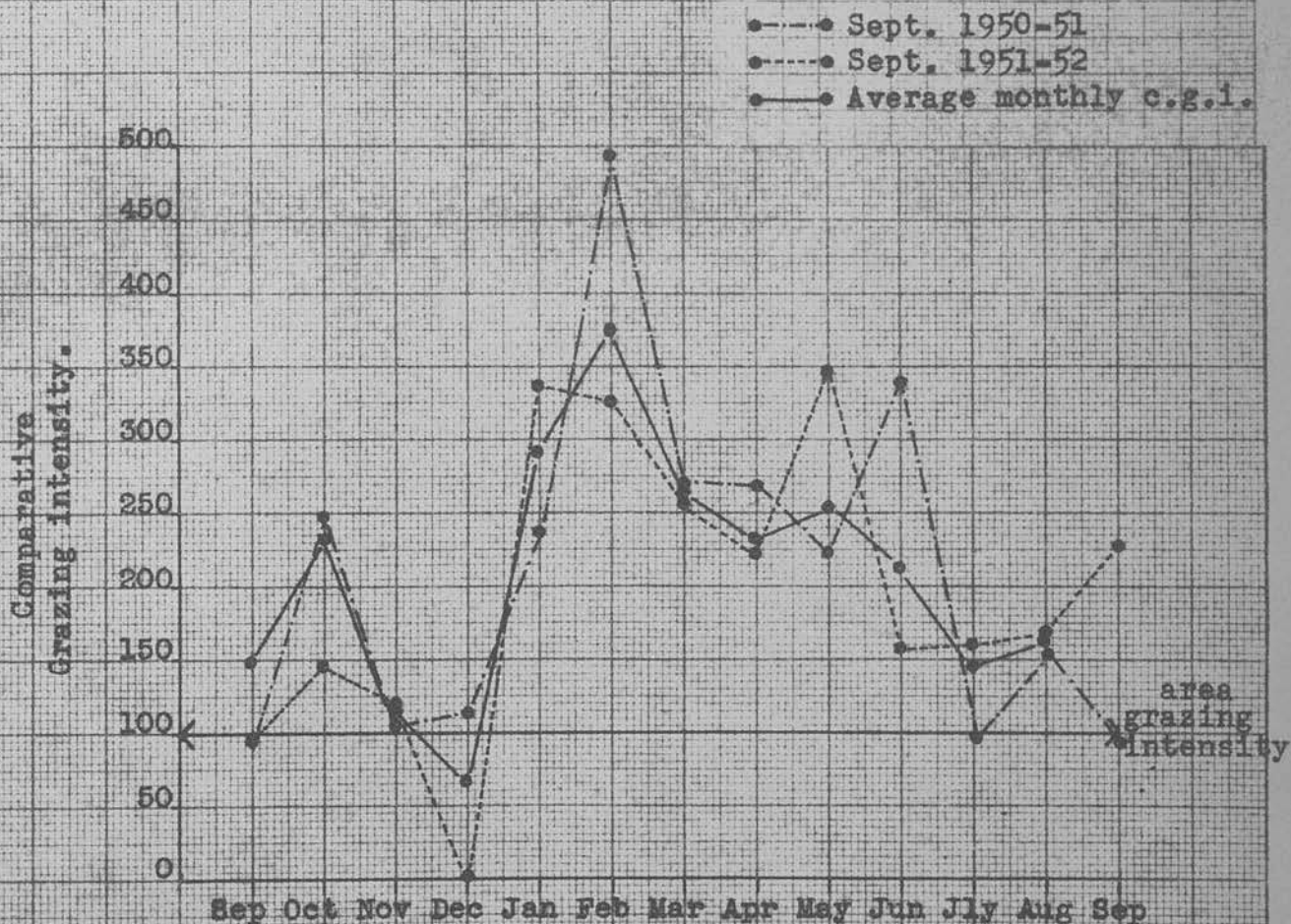
	Monthly c.g.i. Sept. 1950/51	Monthly c.g.i. Sept. 1951/52	average monthly c.g.i.
Sept.	100	113	172
Oct.	279	184	263
Nov.	60	71	67
Dec.	0	14	10
Jan.	249	428	352
Feb.	462	376	398
Mar.	295	286	291
Apr.	326	258	285
May	255	404	292
June	424	187	261
July	126	188	173
Aug.	173	193	187
Sept.	113	247	-

In graph No. 3 the values for the monthly and average monthly c.g.i. are plotted. The close correspondence between the shape of the two curves demonstrates the annual cycle in c.g.i.

The average monthly c.g.i. lies above the area g.i. except for the months of November and December. It is at a low value in November-December then rises rapidly to a peak in February. After February the c.g.i. gradually declines throughout the year until December. The average monthly c.g.i. obscures a feature, common to both the September 1950-51, and Sept. 1951-52 periods, a marked rise in early summer /

Agrostis-fescue Sward

Monthly comparative grazing intensity in periods Sept. 1950-51
& Sept. 1951-52, and average monthly comparative grazing intensity.



occurring in May in 1951-52 and in June in 1950-51.

There is also a rise in October shown by both periods.

Comparison between area 23 and flush area

	Average monthly c.g.i. area 23	Average monthly c.g.i. flush area
Sept.	142	208
Oct.	249	282
Nov.	57	77
Dec.	-	26
Jan.	270	421
Feb.	361	392
Mar.	289	294
Apr.	224	296
May	171	395
June	202	311
July	166	178
Aug.	178	196

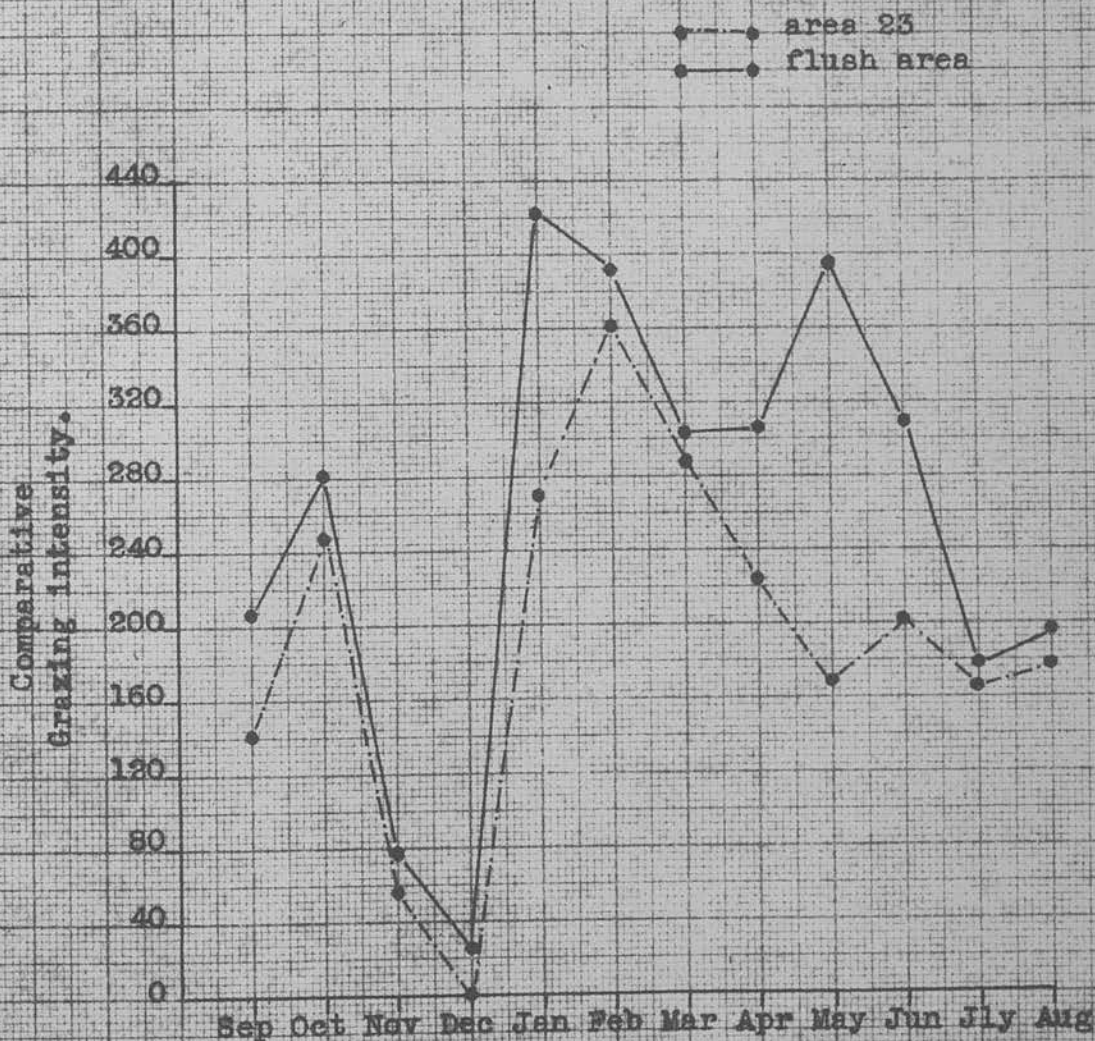
These values are plotted on graph No. 4. There is a close similarity in the shape of the curves and in the actual values of the average monthly c.g.i. in every period of the year except April-June. In this period the c.g.i. on the flush area rises to a peak in May while on area 23 it declines from the high March figure to a moderate value in April-June.

Comparison between the bracken sward and the grass sward free of bracken (= agrostis-fescue grassland composed of areas 22, 23 and the flush area).



Agrostis-fescue Sward

Average monthly comparative grazing intensity on areas 23 & flush area



Average Monthly c.g.i.

	Bracken sward	agrostis-fescue grassland (including nardus)
Sept.	200	148
Oct.	202	231
Nov.	244	115
Dec.	250	67
Jan.	123	291
Feb.	121	374
Mar.	152	265
Apr.	215	233
May	192	253
June	163	214
July	155	145
Aug.	129	165

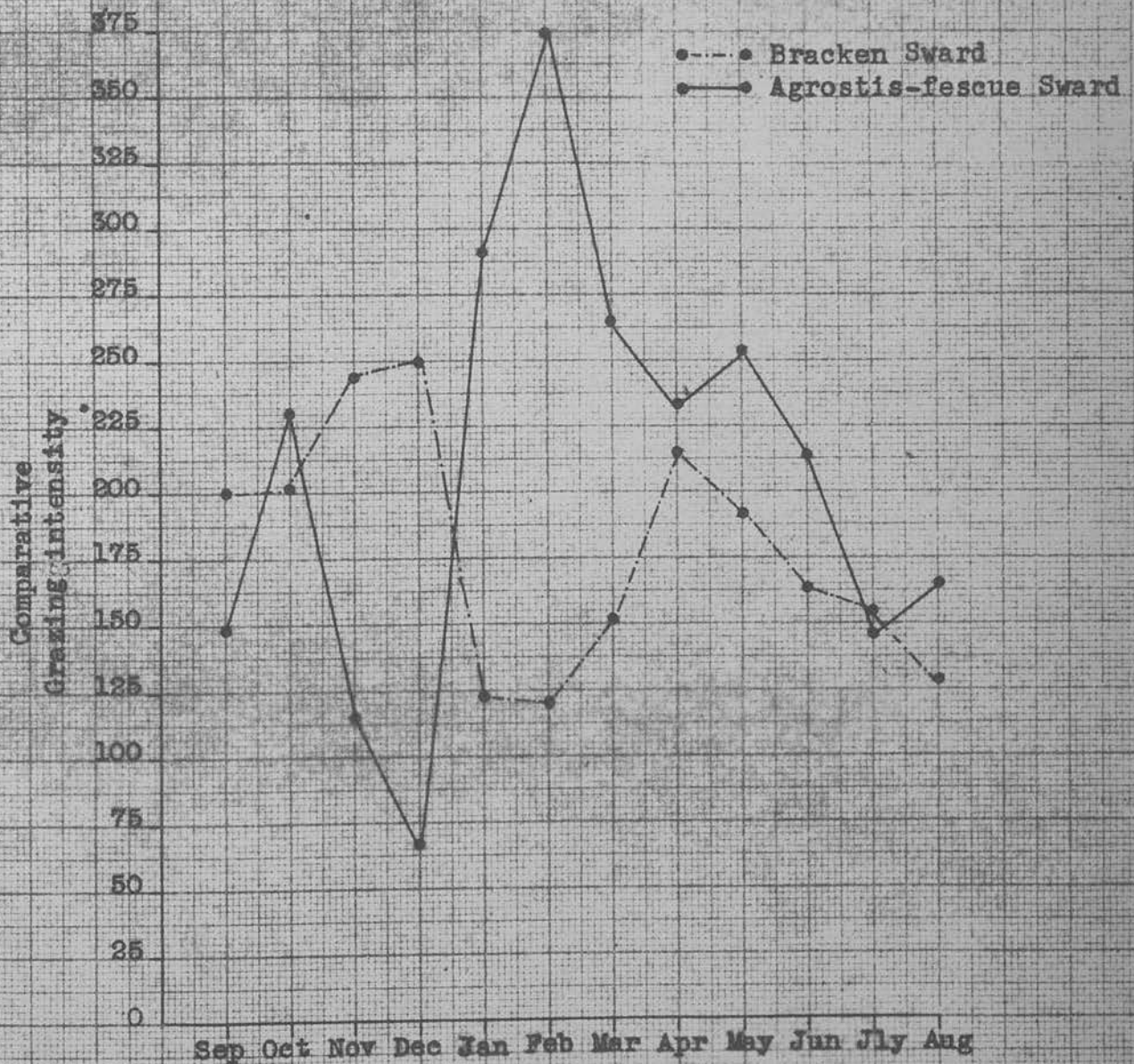
These values are plotted on graph No. 5.

Throughout the period October-April the two curves are complementary and only in May-July are they similar. This comparison shows that bracken sward is a type distinctly different from agrostis-fescue sward and that the effect of a bracken canopy is more than its effect on botanical composition and productivity.

Discussion

Location, and the infestation of much of the total grass area by bracken, play an important part in determining the seasonal variation in c.g.i. on the agrostis-fescue sward. In November-December the sheep are on the high ground. When they come on to the observed area they graze the bracken sward and the c.g.i. on the agrostis-fescue sward is at a minimum. It carries a large quantity of foggage and on the flush area some succulent growth. These are extremely attractive to the sheep in the first /

Average monthly comparative grazing intensity on Bracken
Sward and Agrostis-fescue Sward



quarter of the year. During January-March the c.g.i. on the agrostis-fescue sward is at a maximum and far exceeds the c.g.i. on any other sward. By April the c.g.i. declines to a value not much greater than that of the bracken sward, but as growth begins there is a rise in the c.g.i. The incidence of this peak is related to the season. In the late year, 1950-51, it occurred in June, in the earlier year of 1951-52 it occurred in May. After this the c.g.i. declines until there is a peak in October, a peak which was noticed to occur in both 1950-51 and 1951-52. Heather being no longer attractive will account for this rise, but it is not maintained, as the sheep move off the low ground in November-December.

The average monthly c.g.i. is much greater than the area g.i. except for the months of November-December. Location makes the November-December values lower than they might be if the agrostis-fescue sward was not restricted to the low ground and higher in the first quarter of the year than they might be if bracken did not infest so much of the total grass area. If these allowances are made, then the seasonal variation in c.g.i. on the agrostis-fescue sward is similar to that described by Boulet for the superior swards in his study.

The flush area has the highest average grazing intensity of all the swards and this finding is in line with the high estimation in which flush grass is held in hill farming practice. Indeed such areas are artificially created in the improvement of a hill pasture (44).

More important than its high average grazing intensity is the fact that this sward reaches its maximum c.g.i. in the "lean period" January-March, and in this period exceeds all other swards.

It is not only the flush which attracts the sheep but also the spoil banks which are formed at the side of the drains. Here there is a double depth of soil and these banks are kept closely grazed at all times of the year.

The average monthly c.g.i. on the flush area is very similar to that on area 23 except in the period April-June when a considerable divergence occurs, the c.g.i. on area 23 declining, while that on the flush area is maintained at a high level and shows a peak in May. This divergence exemplifies the very important phenomenon on hill pasture, namely that during the period of spring and early summer growth, the difference in c.g.i. between the superior swards and the inferior is at a maximum. The dominance of Agrostis spp., Festuca spp., C. cristatus and T. repens will be encouraged on the flush area. Differential grazing, especially during /

the growing season, furthers the formation of the different types of sward, a phenomenon shown even more markedly by the small area (area 22) of nardus.

Nardus Sward (2% of area)

Botanical composition

(See Appendix A, Table 11 and Map No. 4)

The small area of nardus sward is dominated by well developed nardus tussocks and shows the typical "white land" appearance in autumn. Festuca ovina is of high frequency and is found growing in the nardus tussocks, whereas the small quantity of Agrostis tenuis tends to grow between the tussocks. Luzula spp. and Potentilla erecta are of higher frequency in the nardus sward than in the agrostis-fescue sward. The sward is floristically poor, 16 species being recorded in the analysis.

Grazing intensity

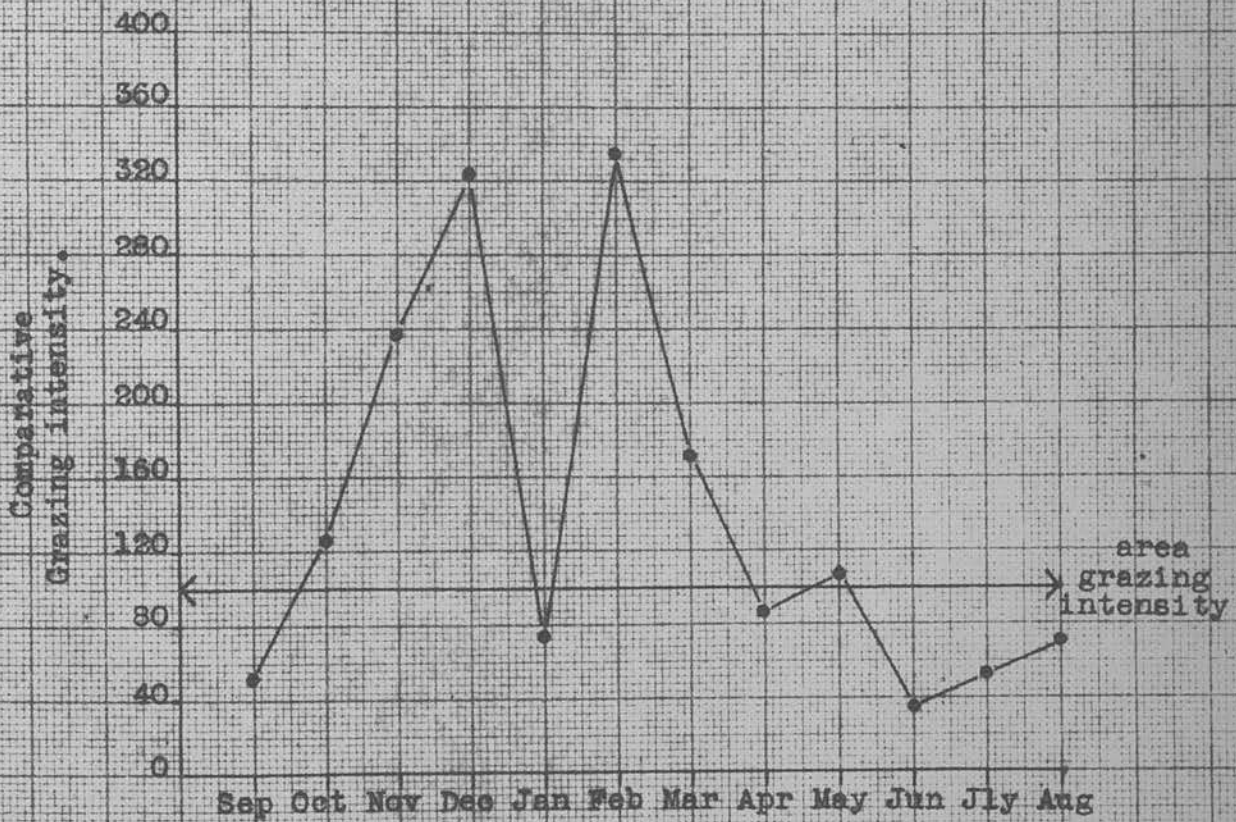
Average Monthly c.g.i.

Sept.	55
Oct.	126
Nov.	237
Dec.	323
Jan.	73
Feb.	336
Mar.	171
Apr.	86
May	106
June	34
July	52
Aug.	70

These values are plotted in graph No. 6. The average monthly c.g.i. rises to its maximum in the period November-March. The low value for January is /

Nardus Sward

Average monthly comparative grazing intensity



thought to be a sampling error. When the area is small such errors are liable to arise.

Discussion

Nardus is regarded as a species of inferior grazing value and its spread over a hill pasture as evidence of deterioration. That the highest c.g.i. occurs in winter is an observation confirmed by Milton (33), Boulet (32), and also by this study, but does not constitute an argument in the sward's favour. The general scarcity of food in winter, the autumn growth of nardus being evergreen, and the accumulation of the ungrazed summer growth of the sub-dominant species in the nardus sward, will attract the sheep to it in winter.

Immediately growth begins in the spring the nardus is neglected and from April-September the c.g.i. is at a minimum far below the area g.i. The location of the nardus sward cannot account for the seasonal variation in c.g.i. as it is sited contiguous to two areas with high c.g.i.-s in spring, summer, and autumn, area 5, and the flush area.

In general, nardus is not found on the low ground but lies below the broken peat of the summit plateau (45). This general location would tend to accentuate the seasonal variation in c.g.i. shown by this area of low ground nardus, as the sheep do not graze the high ground during the growing season but mainly in the last quarter of the year. The seasonal variation in /

c.g.i. on nardus clearly tends to develop dominance of this species, and gives support to the conclusion of Fenton (46); "The dominance of mat grass is therefore a deflected succession and - so long as intensified sheep grazing continues - may be regarded as a selective biotic climax."

Young Heather (15.8% of area)

Botanical Composition

(See Appendix A, Table IV and Map No. 4)

All the young heather areas are of the same age, having been burnt in 1946, and the heather was therefore four years old when the observations began in 1950, and six when they finished in 1952.

The drainage is not greatly impeded on these areas and few bog species, e.g. Empetrum nigrum, Eriophorum vaginatum and Eriophorum angustifolium, were recorded. Except for area 4, they are very similar in botanical composition. Area 4 carries a much less vigorous growth of heather, the peat is only 2" deep, drainage is free and high frequencies of F. ovina and A. canina were recorded. Area 4 is the only young heather area where the heather is not clearly dominant. In the other areas it is, and the accompanying species constitute a very minor proportion of the sward.

Comparative Grazing intensity /

Comparative Grazing intensity

Comparison between periods Sept. 1950 - Sept. 1951
and Sept. 1951 - Sept. 1952

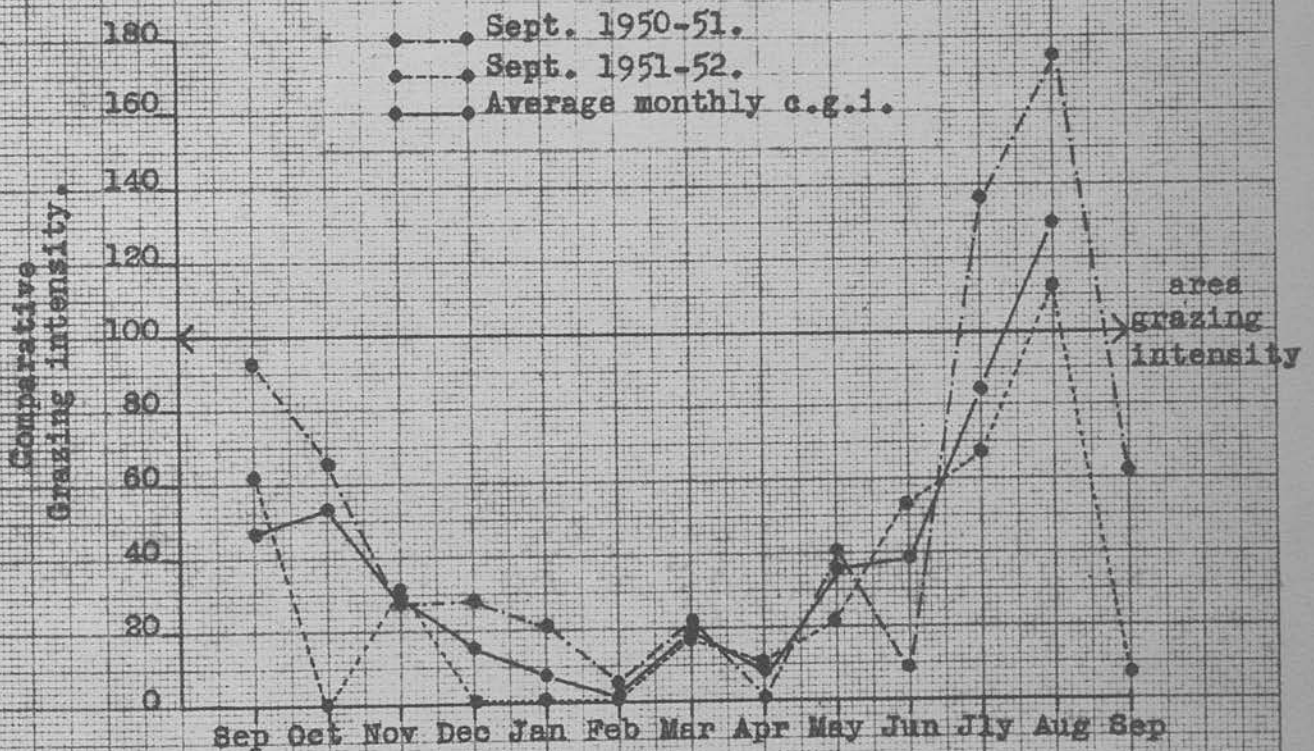
monthly and average monthly c.g.i.

	Period Sept. 1950-51	Period Sept. 1951-52	Average monthly c.g.i.
Sept.	92	62	47
Oct.	65	-	54
Nov.	27	31	29
Dec.	28	-	16
Jan.	21	-	8
Feb.	5	-	1
Mar.	22	17	20
Apr.	-	11	9
May	41	21	36
June	9	53	39
July	137	67	84
Aug.	175	113	130
Sept.	62	7	-
Average c.g.i.	52	29	-

These values are plotted on graph No. 7 and show a close similarity in the shape of the curves of the two periods. The values in the period July-August are, however, greater in the period September 1950-51 than in September 1951-52. Except in the months July-August the values fall far below the area g.i. There is a very marked seasonal variation in c.g.i., which is low throughout the year except for the sharp peak in the period June-September with a maximum value in August.

Young Heather

Monthly comparative grazing intensity in periods Sept. 1950-51
& Sept. 1951-52, and average monthly comparative grazing intensity.



Comparison between areas.

average monthly c.g.i.

No. of area	32	33	34	4
%age of total area	6.30	2.46	6.44	.66
Sept.	1	-	97	175
Oct.	-	142	30	481
Nov.	29	69	8	84
Dec.	-	106	-	-
Jan.	3	-	12	64
Feb.	-	-	3	-
Mar.	24	6	14	76
Apr.	17	5	2	19
May	40	34	11	251
June	40	103	3	139
July	87	189	34	143
Aug.	81	126	182	107

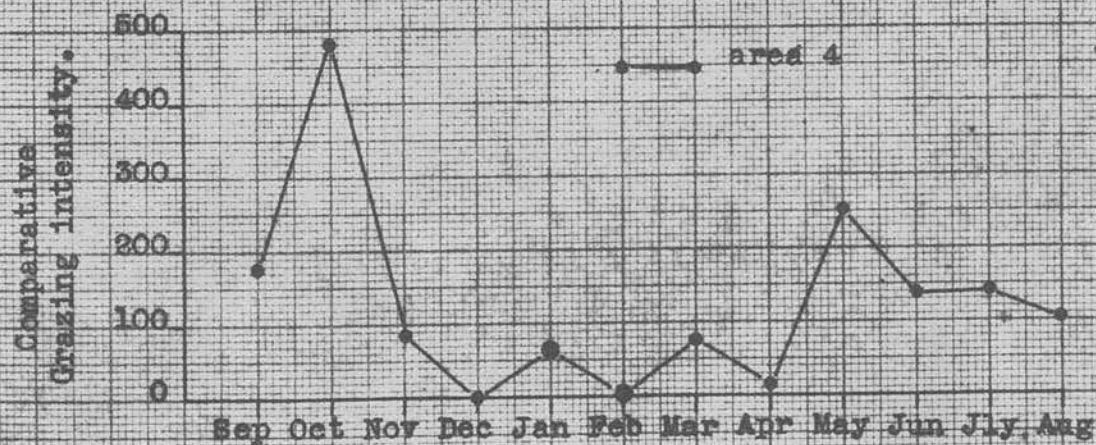
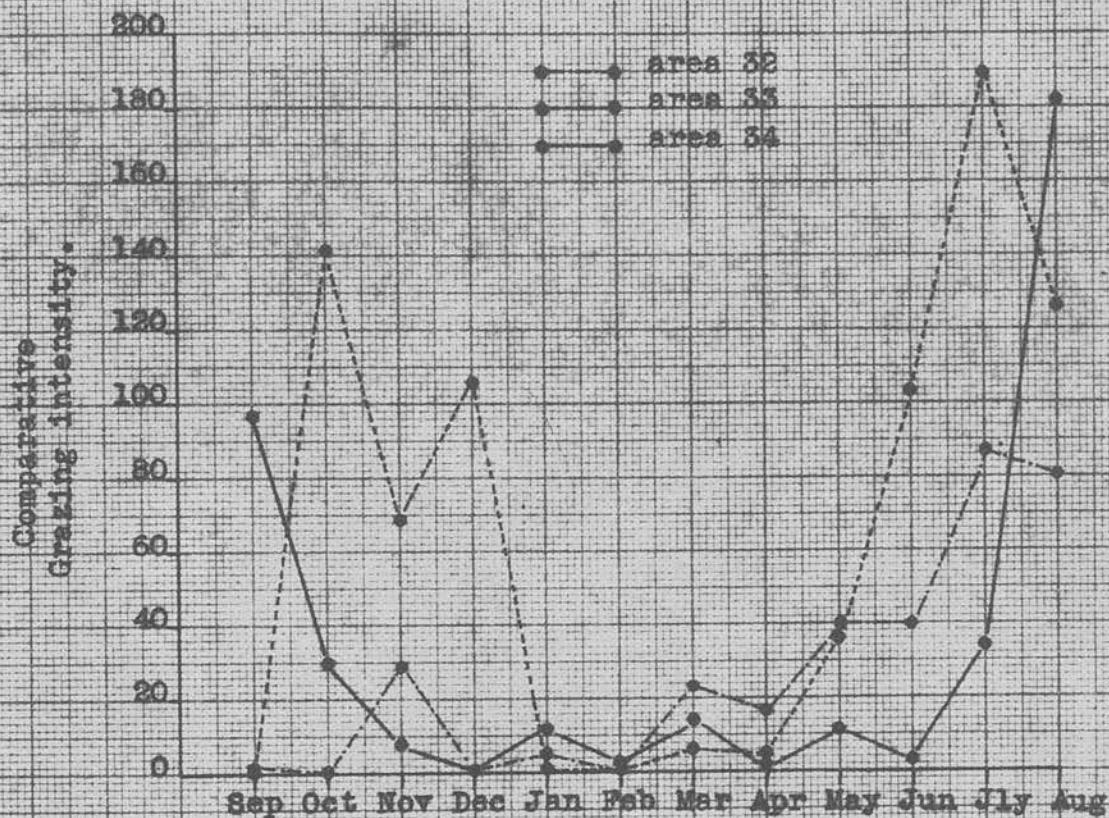
These values are plotted in graph No. 8. The shape of the curves for areas 32, 33 and 34 are very similar except that area 33 maintains a much higher c.g.i. than the other areas in the period October - December. On area 4 the c.g.i. rises earlier in the year than on the other young heather areas, while the late summer peak is maintained until October.

Discussion

The higher c.g.i. in July-August in the period September 1950-51 compared with September 1951-52 may be due to the ageing of the heather. It would be pleasant to give clear proof of this but at least three years' observation would be required to show a trend towards lower c.g.i.-s as the heather aged. The results for one month do, however, extend over a period of three years and they show a downward tendency. The c.g.i.-s for September 1951, 1952 and /

Young Heather

Average monthly comparative grazing intensity on areas 32, 33, 34 & 4



1953 are respectively 92, 62 and 7. Unfortunately this is insufficient evidence for conclusive proof. There is also a very wide difference in the average c.g.i. for the two years. In September 1950-51 it was 52 and in September 1951-52, 29. This again may indicate, that as the heather ages, the c.g.i. declines; a result which would be expected from the chemical analysis of heather of different ages.

The differences between area 4 and the other areas are explained, partly by its botanical composition, and partly by its location. It contains a very high proportion of F. ovina and A. canina and their growth in May will cause the c.g.i. to rise then. When, in July-September, the main young heather areas come into use, the sheep, finding an abundance of heather on them, will not move down the hill to graze the small area 4. The heather growth on area 4 will therefore be "hained" and will be grazed in October when the sheep are concentrating on the agrostis-fescue sward to which area 4 lies in close proximity.

The utilisation of young heather is markedly seasonal. During the period of maximum c.g.i. in July and August the c.g.i. of young heather approaches that of agrostis-fescue sward and, on some areas of young heather, exceeds it. In winter the c.g.i. is very low and in some winter months during the period September 1951-52 there was an almost complete/

avoidance of the young heather sward. Location of the areas cannot account for this as the young heather areas were either contiguous or in close proximity to areas with a high winter c.g.i. There appear to be four contributory causes of the low c.g.i. in winter.

(1) The plants have been so closely grazed in June-September that there is nothing left to graze in winter.

(2) The areas do not contain any quantity of winter-green bog species which would attract the sheep into them.

(3) The growth form of young heather is such that it affords no shelter to the young shoots which are therefore readily frosted and consequently avoided by the sheep in winter.

(4) Thomas (16) suggests, that as the summer: winter variation in chemical composition is less in old heather than in young, the sheep will use the young heather in summer, when it is at its best, and the old heather in winter as it has suffered less deterioration from its summer value.

Old Heather (24.8% of area including areas burnt in November 1951)

Botanical composition

(See Appendix A, Table IV and Map No. 4)

The heather is more than 12 years old and much of it more than 40 years old.

It was felt that there was no point in differentiating between heather areas that were/

more than 12 years old and they are all classed together as old heather. The heather is tall (9" - 24") bushy, and the sward is floristically poor. In the 12 analyses 15 species were recorded with an average of 9 species per area. *Molinia*, though it occurs in 9 of the areas with maximum frequency, is not a co-dominant, being represented by an even dispersion of a few leaves. Thus its frequency is high but it is not quantitatively an important constituent of the sward and it is doubtful if it has much, if any, effect on the grazing. Areas 45, 51 and 49 are exceedingly damp with high frequencies of *Eriophorum angustifolium*.

Comparative Grazing intensity

Comparison between period Sept. 1950-51
and Sept. 1951-52.

monthly and average monthly c.g.i.

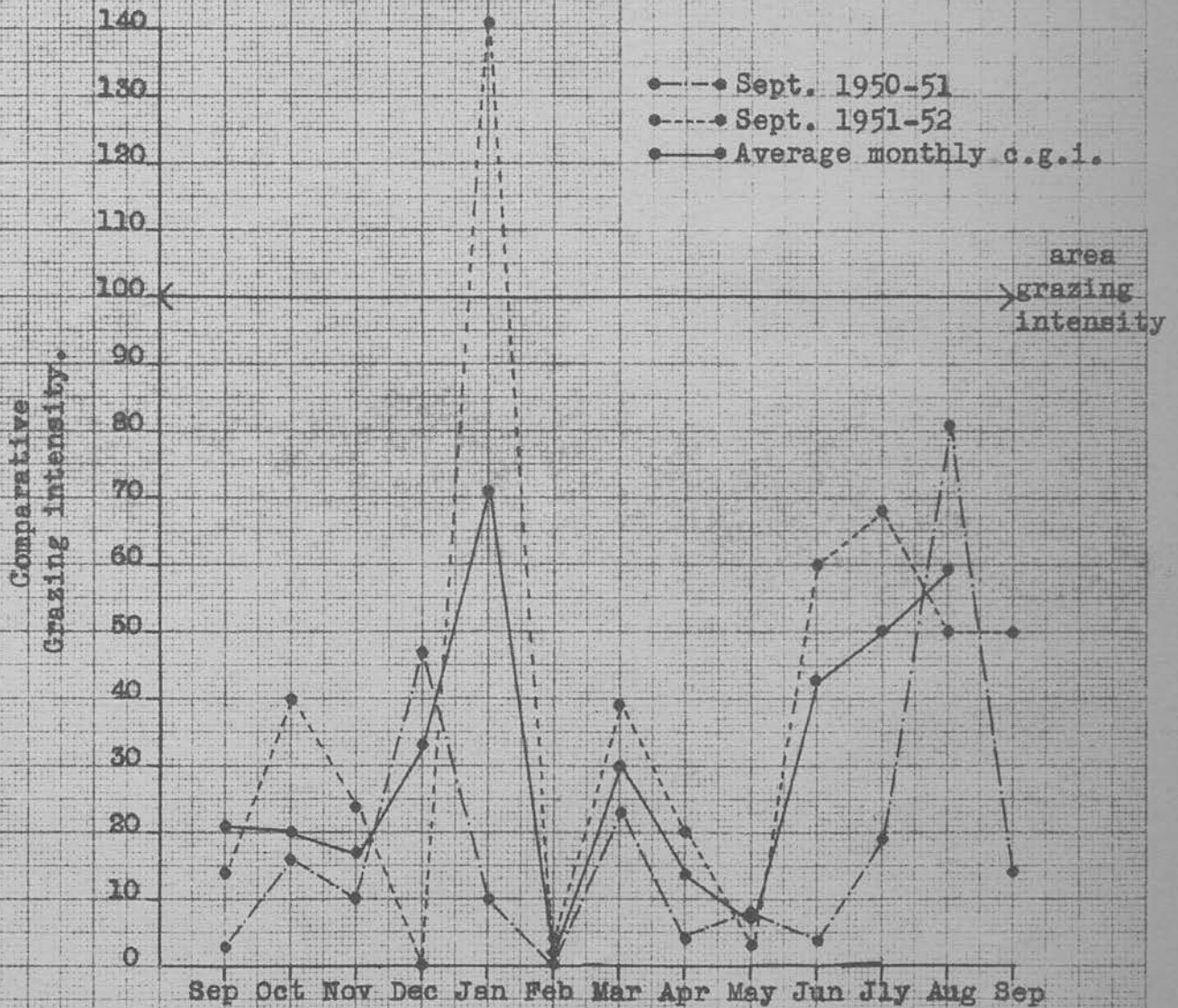
	period Sept. 1950-51	period Sept. 1951-52	average monthly c.g.i.
Sept.	3	14	21
Oct.	16	40	20
Nov.	10	24	17
Dec.	47	-	33
Jan.	10	141	71
Feb.	-	4	2
Mar.	23	39	30
Apr.	4	20	14
May	8	3	8
June	4	60	43
July	19	68	50
Aug.	81	50	59
Sept.	14	50	-

The values are plotted on graph No. 9.

The results are rather unsatisfactory as no clear picture of the seasonal changes in c.g.i. /

Old Heather

Monthly comparative grazing intensity in periods Sept. 1950-51
& Sept. 1951-52, and the average monthly comparative grazing intensity.



emerges from them. In particular the position in the period December-January is obscure, there being no correspondence between the results for the period 1950-51 and 1951-52. It can be said, however, that the c.g.i. is low, the average monthly c.g.i. never exceeding the area g.i. and that there is a peak in c.g.i. in the period June-August and probably another in the period December-March.

Comparison between areas.

average monthly and average c.g.i.

No. of area	52 & 53	55	51	49	45	44	41	38 & 39	37
%age of total area	5.5	.9	.6	2.1	1.0	1.0	3.4	1.3	3.0
Sept.	-	9	-	25	-	-	15	22	-
Oct.	-	-	-	-	-	-	18	59	-
Nov.	-	-	-	13	-	-	41	-	-
Dec.	-	-	-	-	-	-	-	-	-
Jan.	-	-	-	59	821	-	-	131	-
Feb.	-	-	-	-	-	-	-	-	-
Mar.	3	87	-	24	199	15	14	46	-
Apr.	-	77	-	-	42	-	23	-	4
May	2	-	-	-	11	-	3	24	-
June	-	-	-	66	120	-	60	-	44
July	-	12	28	37	29	46	89	-	3
Aug.	-	69	36	68	96	-	105	-	3
average c.g.i.	0.4	21	5	24	109	5	30	22	4

On Map No. 2 some of these areas appear as burnt areas. It should be understood that before being burnt they were old heather areas and the calculation is based on the c.g.i. up till the time of burning.

All the areas fall below the average c.g.i. of old heather (=30) except area 45 which exceeds it and 41 which is at the average value. Thus, on only 5% of the total old heather area, is the /

average c.g.i. exceeded, and then by a very large margin. On 53% of the area, composed of areas 52, 53, 51, 44 and 37 the average c.g.i. is 5 or below.

There are therefore wide differences in the c.g.i. of the old heather areas and a very high percentage of the area is almost completely avoided by the sheep, while a small percentage is grazed with fairly great intensity. The occurrence of a peak in c.g.i. in July-August is apparent. The period October-December shows little grazing on the areas as does the period May-June. March is the only month other than July-August when grazing occurs on at least 7 of the 9 areas and this gives weight to the opinion that old heather is grazed in early spring. The absence of any records of grazing in February is a result which might be expected where the c.g.i. is low and the number of days' observation is small.

Discussion

In the grazing of these areas of old heather there are two points of interest.

(1) The low average c.g.i. of old heather and the wide variation in the c.g.i. between the different areas of old heather.

(2) The ratio of winter:summer c.g.i.

The adverse opinion about old heather is confirmed by this study of its c.g.i. Large areas of the old heather are not grazed. If they were fenced from the stock, and planted with trees, it /

would only improve the grazing by providing shelter. Until they are burnt they are useless.

The considerable variation in c.g.i. between the areas is a location effect, and also an indication that the heather is too large a proportion of the area for its efficient utilisation. It is probable that sheep will take a limited quantity of old heather as a proportion of their diet and ignore any excess. Where it is in excess, the areas they will utilise will be those adjacent to their main grazing areas. The distant areas will be ignored.

We are touching here the very important question of the most advantageous proportion of heather on a hill pasture. It should be sufficiently large not to suffer progressive reduction through over-grazing and should not exceed the amount the sheep are prepared to consume as a proportion of their diet. Linton (13) advises that the proportion should be $1/7$ of the pasture but does not state how he arrived at that figure, or if it refers to heather areas on the high or low ground, or what proportion the other swards should be if heather is $1/7$. It should be, however, a relatively simple question for a hill farmer or a shepherd, to decide if the heather on any heft is being over- or under-grazed, and this, and not the proportion it forms of the pasture, is the important point.

(2) The ratio of winter: summer c.g.i.

The ratio of winter (January-April) to summer (June-September) c.g.i. on old heather is 29:43, and on young heather, 9:75. The reasons why young heather is lightly grazed in winter have already been discussed. The much smaller winter:summer ratio characteristic of old heather ^{may} arise from the following contributory causes.

(1) In old heather both the rate and the amount of growth in summer being less than in young heather.

(2) The chemical composition of old heather not varying greatly between summer and winter so that old heather is not much less attractive in winter than it is in summer.

(3) Heather being in excess in the pasture, the sheep have a choice between young and old heather in summer and as they prefer the former the c.g.i. does not rise on the latter.

(4) There being more wintergreen bog species in the old heather than in the young, these may attract the sheep into the old heather in winter.

(5) The growth form of old heather affording shelter to the tips of some shoots and hence saving them from frost damage.

Comparative grazing intensities were calculated omitting those days of observation on which the ground was covered with snow, since the snow would interfere with the free choice of the sheep among /

the swards, and would hence affect the results.

If the days, on which the snow cover was deep, were included in the calculations, the c.g.i. on old heather in winter would greatly increase. On many days it was the only plant which could be grazed as the sheep were able to shake the snow off the old bushy heather with great ease. It was only with great difficulty that they were able to graze the other swards when the snow was deep, and sometimes it was impossible. It is for this reason that many herds like to have an area of old heather near a stiel as it affords the sheep a readily available bite during periods of storm. It is the recognition of such points as these which makes the management of hill pastures something of an art.

Lea Heather (6.4% of the total area)

Botanical composition

(See Appendix A, table IV and Map No. 4)

The two areas, 42 and 43, are composed of heather more than 12 years old, and contain within them outcrops of stone and patches of grass sward. The peat lying between these varies from one inch to twelve inches deep, is fairly well drained and bog species are absent. The description, lea heather, is not quite accurate but it has been used to distinguish these areas from other areas of old heather occurring on deep, badly drained peat and associated with bog species.

As would be expected the areas are floristically richer than the other areas of old heather. A total of 15 species in the two analyses, and an average of 12 species per analysis were recorded. Such typical bog species as Eriophorum vaginatum and angustifolium, Empetrum nigrum and Erica tetralix do not occur.

Comparative Grazing intensity

Comparison between the periods Sept. 1950-
Sept. 51 and Sept. 1951-Sept. 52.

monthly and average monthly c.g.i.

	period Sept. 1950-51	period Sept. 1951-52	average monthly c.g.i.
Sept.	168	70	89
Oct.	-	-	-
Nov.	33	105	81
Dec.	-	-	-
Jan.	98	174	142
Feb.	-	232	165
Mar.	23	154	79
Apr.	-	31	25
May	42	118	61
June	126	121	122
July	224	82	121
Aug.	-	89	64
Sept.	70	50	-

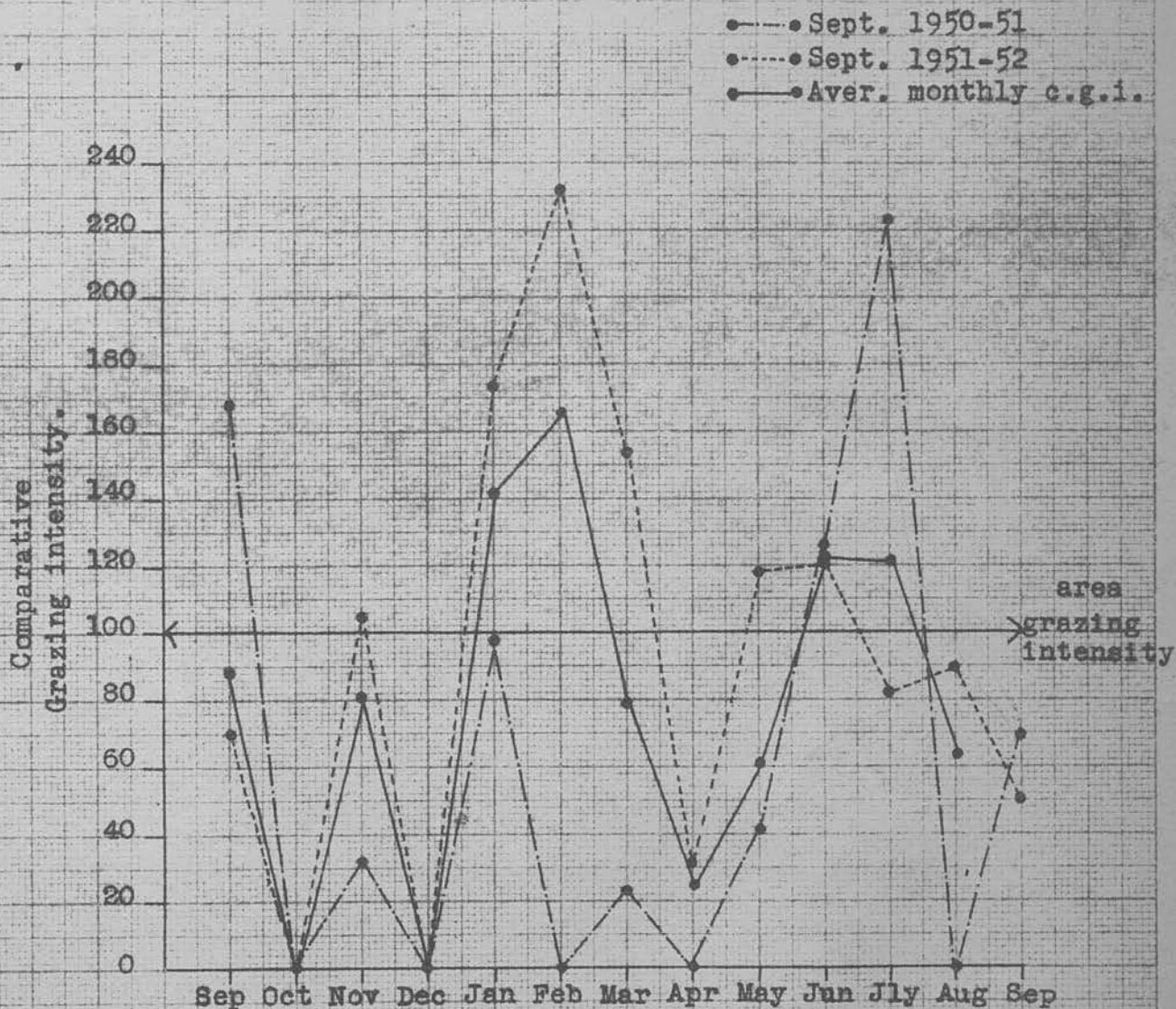
These values are plotted on graph No. 10.

The c.g.i. in 1950-51 is much less than in 1951-52 but the correspondence of the curves is quite good, February and August being the only months in which they are contradictory. There are two peaks in the c.g.i., a winter peak in the period January-March and a summer peak in the period June-July. The c.g.i. begins to increase in May from the low value in April.

In both the periods January-February and June- /

Lea Heather

Monthly comparative grazing intensity in periods Sept. 1950-51
& Sept. 1951-52, and average monthly comparative grazing intensity.



July the area g.i. is exceeded.

Comparison between areas.

average monthly and average c.g.i.

No. of area	42	43
%age of total area	3.19	3.24
Sept.	36	140
Oct.	-	-
Nov.	66	96
Dec.	-	-
Jan.	78	204
Feb.	92	235
Mar.	82	75
Apr.	12	37
May	45	77
June	130	114
July	142	100
Aug.	60	69
average c.g.i.	62	95

These values are plotted in graph No. 11.

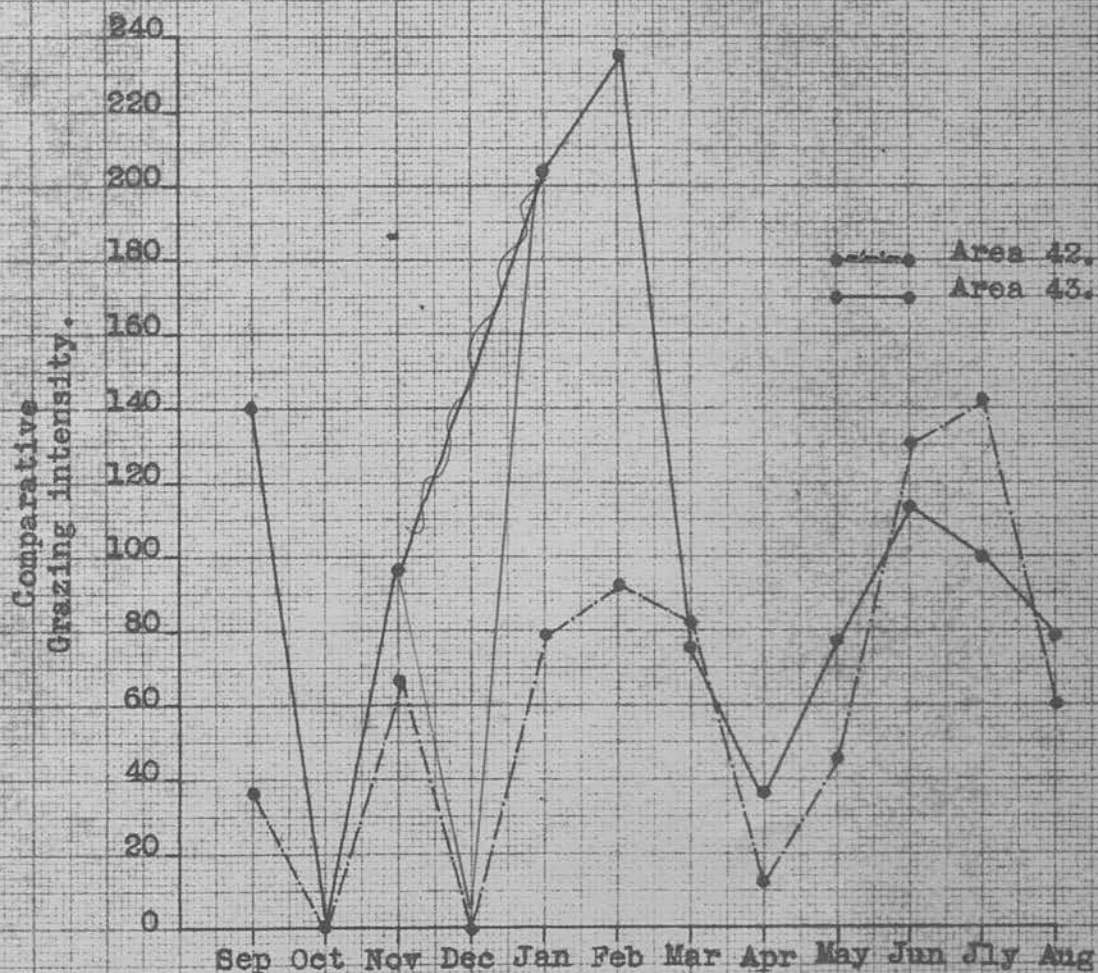
While the average c.g.i. is higher on area 43 than on area 42, there is a very close correspondence between the curves for the two areas. Only in July, when the c.g.i. on 43 increases and on 42 decreases, are they not identical. The slightly lower altitude of area 43, its proximity to the areas of draw moss, and the greater proportion of grass areas in it, may account for the difference in the c.g.i., between it and area 43, in the period January-February. At other times of the year the c.g.i. on the two areas is very similar.

Discussion

The old heather in these areas is a valuable sward. It is well grazed in the months of January-February and is comparatively early, the c.g.i. rising in May and reaching a summer maximum in June or July./

Lea Heather

Average monthly comparative grazing intensity on areas 42 & 43.



It cannot be said if the earlier spring rise in the c.g.i., in comparison to the other heather areas, e.g. old and young heather, is due to the grass content of the sward or to the earlier growth of the heather. The latter explanation appears the more likely, as grass is only a small proportion of the sward, and the sheep have an abundance of grass on other areas. If growth is earlier in these lea heather areas this may be due to their more freely draining peat becoming warm in the spring before that of the peat below the bog heather. Certainly its summer peak in grazing lies in June and July, and not in July and August, as is the case on the other heather areas. The grazing of these old heather areas, areas 43 and 42, would support an opinion of Linton's (13), which Thomas questions, that age is not the only factor determining the value of heather, nor is value inversely related to age.

Winter and Summer Comparative Grazing Intensities
on Different Types of Heather

This point has already been discussed but its practical importance makes it merit further consideration. The table below shows the winter, (January-April) and summer, (June-September) comparative grazing intensities on the different types of heather sward at Overshiels. /

Heather Sward Type	Comparative grazing intensity	
	Winter period	summer period
Young heather	9	75
Old heather	29	43
Lea heather	103	99

Young heather has a high c.g.i. in summer, certain areas surpassing all other heather areas at this time, and is almost completely avoided in winter. The old bushy heather, growing in deep peat, has a low c.g.i. in both periods, but the summer:winter variation is not very great. Lea heather (as defined in the text) has a high c.g.i. in both periods, and practically no winter:summer variation in c.g.i.

The following conclusions are drawn from these facts. The burning of heather greatly increases the yield, but appears to reduce the quantity available for winter grazing. Certain types of old heather are extremely valuable, being heavily grazed in both summer and winter, while other types of old heather are of low or almost no value at all times of the year.

The contributory causes of the low c.g.i. on young, and higher c.g.i. on old heather, in winter, have already been suggested. Of these causes, the one to which the writer would give most weight, is the growth form of the heather plant.

On the 19th March 1953 the heather areas at Overshiels were closely inspected and the following points noted. On the young heather all of the /

preceding season's growth was exposed to both wind and sun. The leaflets facing the south on each sprig of heather were frosted and of a foxy brown colour. The leaflets, on the side of the sprig facing away from the sun, were green and apparently unfrosted. It is therefore likely that frosting is caused, not by the freezing of the leaflets, but by their being rapidly thawed out by the sun.

On the old heather some of the sprigs were green and had a fresh appearance. These sprigs appeared to have developed from buds which had remained dormant until some time after the plant was well grown, and their subsequent growth was therefore sheltered. The presence of unfrosted growth from the preceding summer in the old heather, and the lack of it in the young heather, is probably the explanation of the sheep's winter preference for old heather. If this is the case, it might be a practical proposition to plant, not shelter, but shade belts, to protect young heather from the winter sun and thus preserve considerable quantities of heather for winter grazing.

While it is true that heather should not be allowed to get very old, and it is generally recommended that it should be burnt at 10-12 year intervals, this is a recommendation requiring intelligent application. Until we know more about the growth, and response to grazing of heather on /

different soils, its susceptibility to frost damage, its growth habit, the proportion of the pasture heather should constitute, and the best proportion of different ages of heather, its management will not be fully understood.

The type and location of some heather areas may make it advisable to burn once in seven years, in other cases once in twenty years might be the best interval.

Certainly, without deep knowledge of the particular conditions of each hill, intelligent management of its heather sward is impossible, and in this connection, the practice of game keepers being in charge of heather burning, is little short of ridiculous.

Draw Moss (4.16% of area)

Botanical composition

(See Appendix A, Table IV, and Map No. 4)

There are five areas of draw moss but in only one of these, area 54, is it so well developed that it is dominant over heather and attains the highest frequency class. In the other areas the draw moss occurs as tussocks growing among the heather. In area 51 draw moss is of fairly high frequency but this area is not included among the draw moss areas as there the draw moss is quantitatively insignificant and the tussock formation poorly developed. The heather accompanying the draw moss is old, and the /

peat deep.

Comparative Grazing intensity

Comparison between periods Sept. 1950 - Sept. 1951
and Sept. 1951 - Sept. 1952.

monthly and average monthly c.g.i.

	Period Sept. 1950-51	Period Sept. 1951-52	Average monthly c.g.i.
Sept.	21	39	27
Oct.	-	82	14
Nov.	-	-	-
Dec.	-	-	-
Jan.	-	165	95
Feb.	80	51	60
Mar.	129	198	151
Apr.	74	15	26
May	27	10	23
June	-	-	-
July	-	19	14
Aug.	117	19	46
Sept.	39	5	-

These values are plotted in graph No. 12. The total area of draw moss is small, and as could be expected, there is considerable variation in the values between months and between years. Nevertheless, there are clearly two periods when the sward is utilised; the first from January-April and the second from August-October. Except for March the average monthly c.g.i. lies below the area g.i.

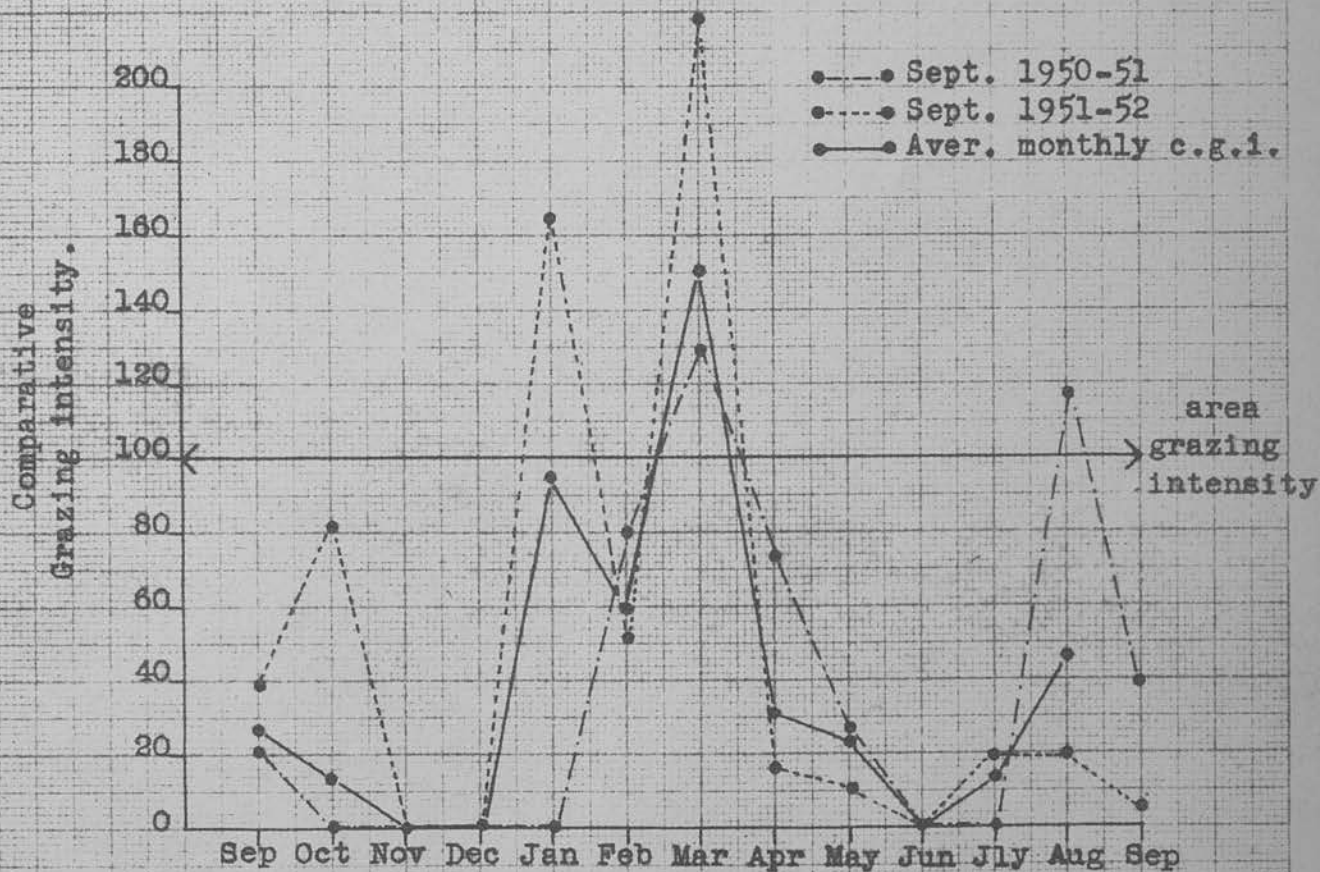
Comparison between areas of draw moss sward.

average monthly c.g.i.

No. of area	46	47	48	50	54
%age of total area	1.69	0.35	0.89	0.57	0.66
Sept.	37	-	-	46	53
Oct.	-	-	-	-	95
Nov.	-	-	-	-	-
Dec.	-	-	-	-	-
Jan.	61	-	-	239	250
Feb.	37	-	-	-	319
Mar.	160	-	42	-	589
Apr.	-	-	-	-	183
May	7	31	57	-	53
June	-	-	-	-	-
July	-	46	27	28	16
Aug.	52	46	26	47	91
Average c.g.i.	29	10	13	34	132

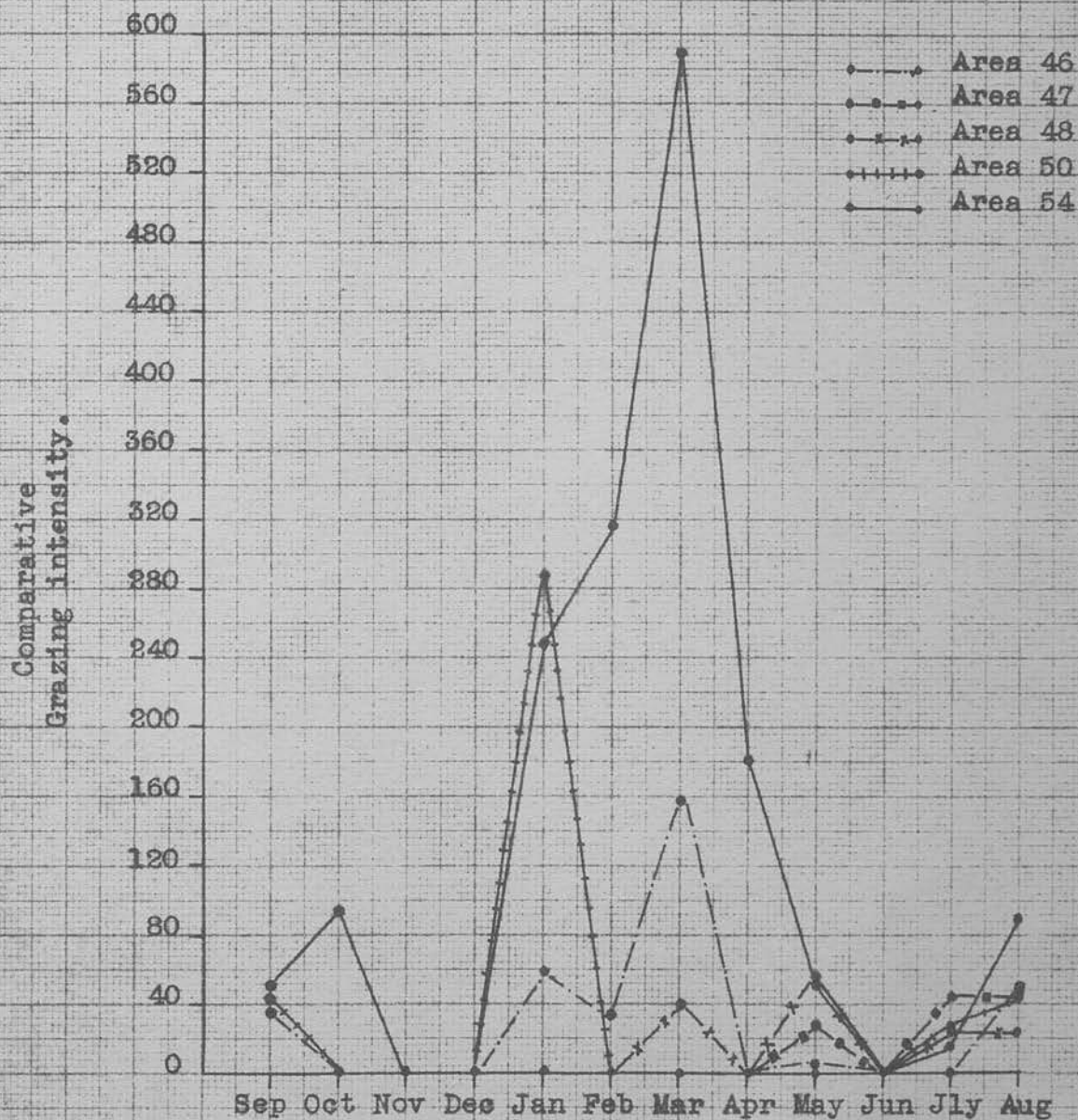
Draw Moss

Monthly comparative grazing intensity in periods Sept.1950-51
& Sept.1951-52, and average monthly comparative grazing intensity.



Draw Moss

Average monthly comparative grazing intensity on areas 46, 47, 48, 50, & 54.



These values are plotted in graph No. 13.

In the comparison between areas the most obvious feature is the outstanding difference between the grazing intensity on area 54 and all the others. All the areas show a peak, or peaks, in grazing intensity in the period January-May and smaller peaks in the period July-October. On small areas where the grazing intensity is low, it is not expected that changes in average monthly c.g.i. will emerge as clearly as they do in large areas with a high c.g.i. However, except for area 47, where the c.g.i. in the period January-May is very low, the curves for all the areas of draw moss sward are broadly similar.

Discussion

All the writers are agreed that draw moss is of value in the early spring, especially if sited on the low ground, and Wallace has said that many a farmer has "...ruined his farm, his stock, and himself" by draining draw moss bog (14). The chemical analysis of Thomas is further proof of the value of draw moss in the early spring and the seasonal variation in c.g.i. certainly indicates its use in this period. Indeed, of all the areas of draw moss, the area which contains the greatest quantity of draw moss is the one with the highest c.g.i. in the period January-April. The slight rise in c.g.i. which occurs in July-August is due to the heather content in the sward and is much less than the rise /

in January-March.

Burnt Heather (5.9% of total area)

Botanical composition

(See Appendix A, Table IV and Map No. 4)

Botanical analyses were made of the burnt heather areas in the summer of 1952. The areas were burnt in November 1951. The heather was successfully regenerating on all the areas except area 39. This had been an area of very dense, tall heather, similar to areas 38 and 40, on which areas the peat was thin and dry and where only 6 species were recorded at each analysis. In half of the quadrat readings on area 39 no young heather shoots were recorded, indicative of very poor regeneration.

The amount of available grazing was small on all the burnt areas. It was noted that the molinia was well grazed while J. squarrosus and T. caespitosum, were available on the burnt areas in the winter following burning.

Comparative Grazing intensity

Comparison between areas before and after burning:

	(Monthly c.g.i. before burning)	(Monthly c.g.i. after burning)
Nov.	-	(Burnt Nov. 1951)
Dec.	-	-
Jan.	32	-
Feb.	-	-
Mar.	15	17
Apr.	-	-
May	24	40
June	-	85
July	8	73
Aug.	13	78
Sept.	5	51
Oct.	-	-

The c.g.i. on the areas before burning was very low, and during some months they were not grazed. As can be seen the burnt areas were, in their first year, grazed in the period March-September. It is thought that the fresh, and after burning, readily available, shoots of molinia attract the sheep in the months of May-June. In the months July-September the young heather growth is grazed, while in March J. squarrosus and deer hair attract the sheep to the recently burnt areas.

Discussion

The c.g.i. on the burnt areas is moderately high and is in the order of that on a representative area of mature molinia (area 17) in the period June-September. The D.M. production per unit area of the mature molinia sward is certainly many times higher than that on the freshly-burnt heather areas yet their grazing intensities are roughly equivalent. If anything, the burnt areas are slightly higher. Growth is less on the burnt areas than on the molinia sward, but it is all young fresh growth.

This is a clear demonstration that the sheep graze for quality and a further proof that c.g.i. is not in direct proportion to productivity.

Molinia sward (7% of area)

Botanical composition

(See Appendix A, Table 11, and Map No. 4)

This is bog molinia in which the large molinia tussocks are the most conspicuous feature of the /

vegetation. There are fairly wide differences between the several areas of molinia. Area 19 has a high frequency of F. ovina and N. stricta and is much drier than the other areas. Area 17 is the dampest of the areas and shows small frequencies of J. squarrosus, heather, Vaccinium myrtillus and Vaccinium vitis-idaea and there is a trace of Erica tetralix. Areas 14-16 are drier than 17 and contain a fair representation of F. ovina. Area 21 is not considered as it cannot be satisfactorily classified as molinia. The molinia sward is floristically poor, 22 species in the 5 analyses and an average of 13 per analysis being recorded.

Comparative grazing intensity

Comparison between periods Sept. 1950-Sept. 1951
and Sept. 1951-Sept. 1952.

Monthly and average monthly c.g.i.

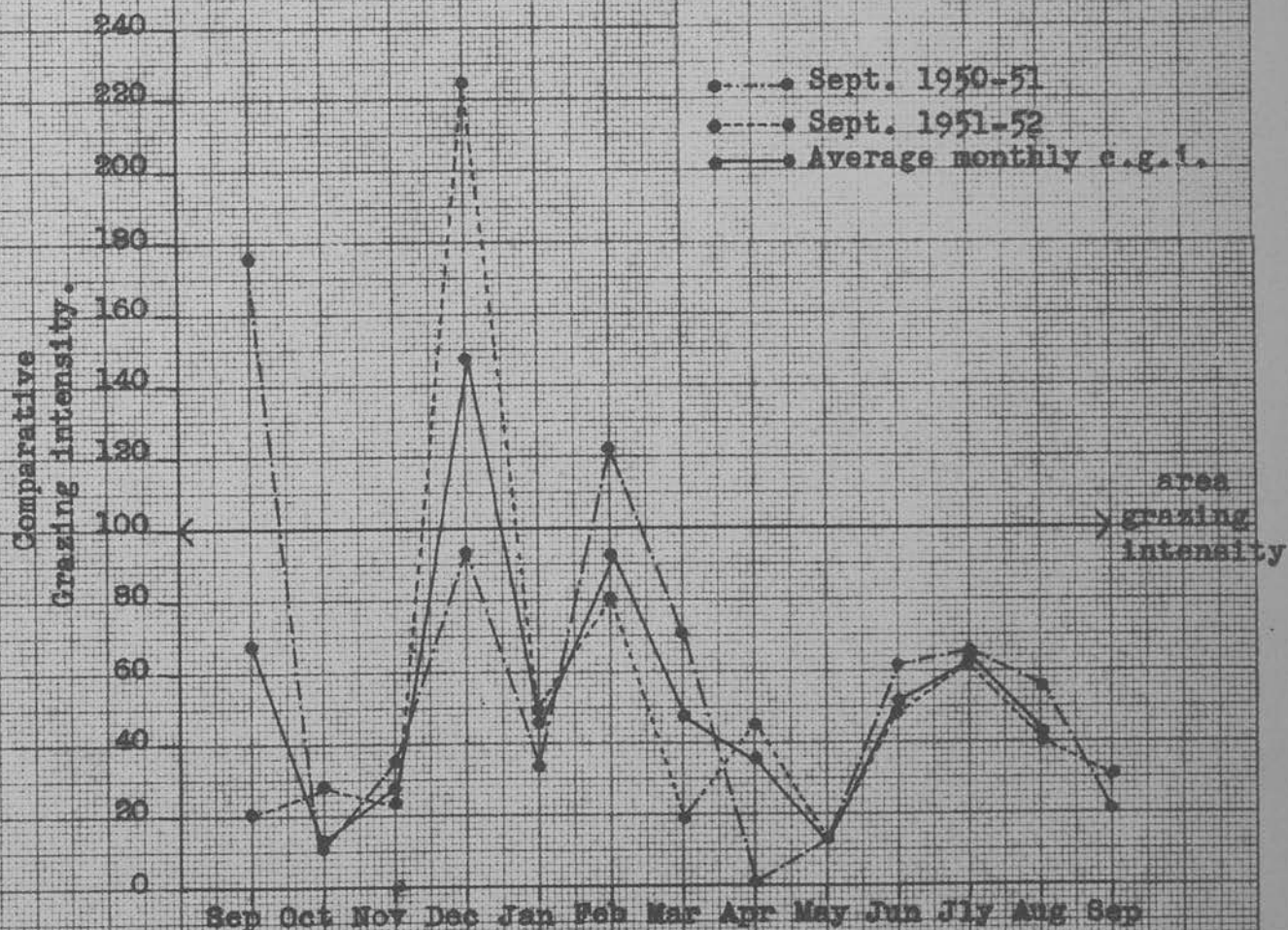
	period Sept. 1950-51	period Sept. 1951-52	average monthly c.g.i.
Sept.	176	21	68
Oct.	11	29	13
Nov.	36	24	28
Dec.	94	225	148
Jan.	34	52	47
Feb.	123	81	93
Mar.	71	19	48
Apr.	-	45	36
May	13	13	13
June	62	48	52
July	66	62	63
Aug.	47	40	42
Sept.	21	31	-

The values are plotted on graph No. 14.

It has to be remembered that molinia itself affords no grazing during the winter period and is only available in the period May-September. There /

Molinia Sward

Monthly comparative grazing intensity in periods Sept. 1950-51
& Sept. 1951-52, and average monthly comparative grazing intensity



is an increase in the c.g.i. in the period May-July which is thought to be due to the early growth of the molinia. The c.g.i. then declines in August-September. Only in December does the average monthly c.g.i. exceed the area g.i. During the summer period it, like nardus and old heather, fails to exceed the area g.i.

Comparison between areas.

average monthly and average c.g.i.
molinia areas.

No. of area	20	19	18	17	16	15	14
%age of total area	0.32	1.44	0.32	3.48	0.28	0.40	0.82
Sept.	25	118	-	62	189	-	42
Oct.	-	-	-	27	-	-	-
Nov.	-	38	-	36	-	35	-
Dec.	-	544	-	-	-	-	318
Jan.	-	-	-	53	71	50	125
Feb.	-	140	-	73	528	-	51
Mar.	-	6	50	31	332	62	113
Apr.	-	121	-	23	-	-	-
May	-	-	30	24	-	-	-
June	-	63	-	40	328	115	-
July	34	85	-	74	139	27	6
Aug.	-	30	-	64	39	12	20
Average c.g.i.	5	95	6	42	135	25	56

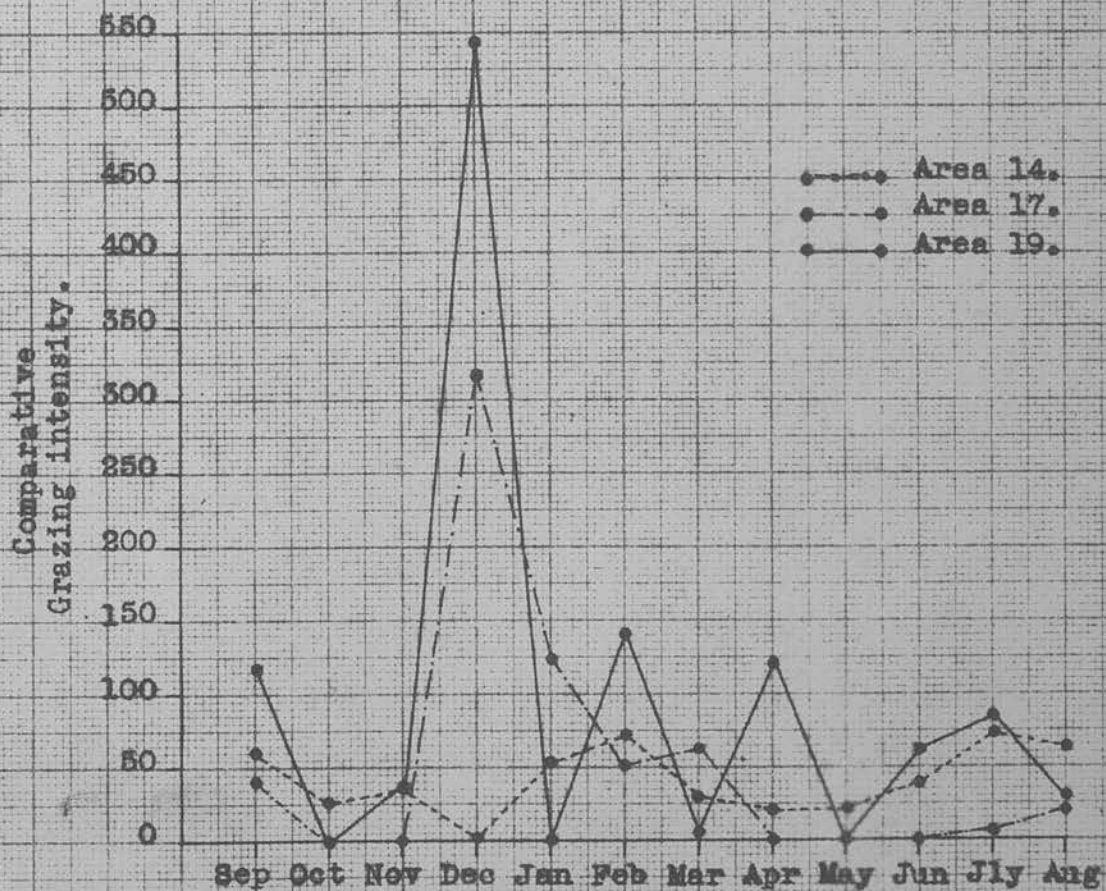
Some of these results are plotted on graph No. 15.

The highest intensities occur in the December-March period and again in the period June-September, April-May and October are periods of low c.g.i. The very small areas with low c.g.i.-s, areas 16, 20, 18, and 15 are omitted from further consideration because they are small and liable to give misleading results.

Area 17 is thought to give the most reliable indication of the seasonal changes in the c.g.i. as it shows consistent trends with no wide variation, is the largest area of molinia, and being situated in /

Molinia Sward.

Average monthly comparative grazing intensity on areas 14, 17 & 19



close proximity to the main grazing areas, it offers the sheep the choice of grazing or avoiding it. These considerations also apply in some measure to area 14 which has a curve rather similar to area 17. Area 19 is not sited in close proximity to the main grazing areas and here the results are very erratic. It has, however, certain similarities to areas 17 and 14 in that there is a peak in the winter, a low value in May and a further peak in the period June-September. The molinia sward has two periods of above average utilisation, a period from December-March and another in the period from June-September.

Discussion

There is a certain similarity in the grazing of molinia and nardus swards. Both show a peak in the c.g.i. in the winter, a peak that is related to the scarcity of food that makes the sheep search these swards for uneaten summer growth. In the molinia sward it is obviously not the molinia they graze but the sub-dominant Agrostis spp. and Festuca spp.

Here the similarity ends, molinia having a peak in the c.g.i. which rises in June and falls in September. This peak does not rise to the level of the area g.i., thus indicating either that the grass is of marked inferiority, or that other factors are causing an under-utilisation. Under-utilisation may be due to the counter-attraction of the heather, especially the lea and young heather. When molinia reaches its maximum growth, towards the end of June, heather is at its most palatable stage and the sheep graze the /

heather in preference to the molinia. This is an example of the utilisation of a sward being affected by the other types of sward present in the pasture. Had the heather not been present it is probable that the molinia would have been grazed much more intensively.

Comparison between Swards

That each sward has a characteristic seasonal variation in the c.g.i. has already been shown and discussed. In making a comparison between the swards the data have been further reduced. The average bi-monthly c.g.i. has been calculated and all the heather areas have been grouped together.

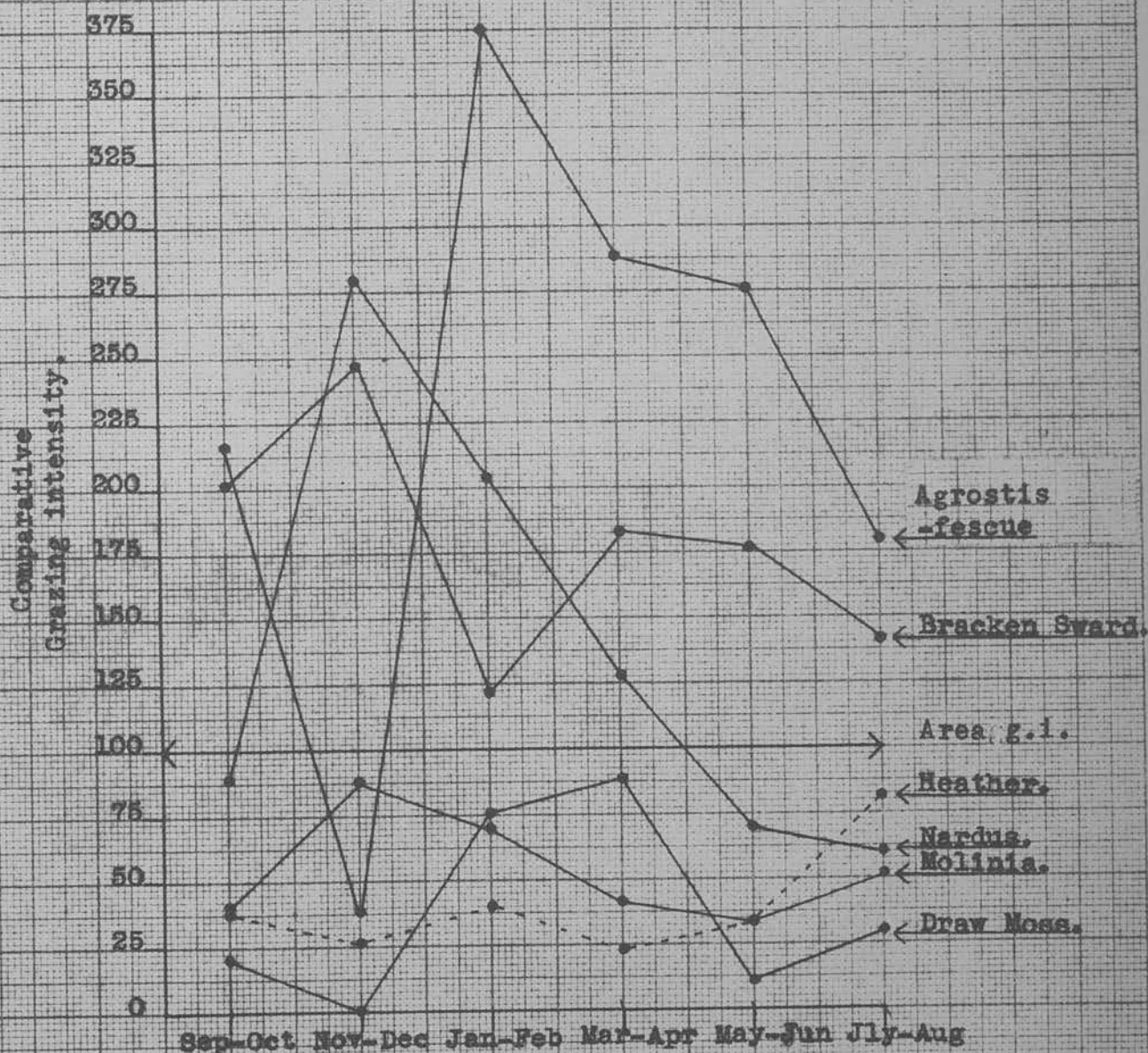
average bi-monthly c.g.i.

Sward -	Bracken sward	Agrostis-fescue	Molinia	Heather (less burnt heather)	Nardus	Draw Moss
%age of total area	29.46	9.65	7.06	41.22	2.02	4.16
Sept.-Oct.	201	217	41	38	89	21
Nov.-Dec.	247	38	88	27	280	-
Jan.-Feb.	122	375	70	40	204	77
Mar.-Apr.	183	238	42	24	128	88
May-June	177	276	34	33	70	11
July-Aug.	142	180	52	82	61	30
average c.g.i.	130	211	56	41	138	43

These values are plotted in graph No. 16.

Graph No. 16 shows the wide variation in the c.g.i. which exists among swards. Agrostis-fescue sward is superior in every period except the November-December one, the superiority being most marked in January-February and declining from that period onwards. Nardus has very high values in the November-February period, (it must be remembered that this is nardus sited on the low ground) but during the growing season the values fall below the area c.g.i. Molinia has a low value at all

Average
bi-monthly comparative grazing intensity on different swards.



times of the year and shows a similarity to nardus in that the highest c.g.i.-s occur in winter. The bracken sward is second to the agrostis-fescue sward and the c.g.i. never falls below the area g.i. As already noted the bracken sward and agrostis-fescue sward curves are complementary in the period September-April and from April to September they both show a gradual decline. The values for draw moss never exceed the area g.i. but from January-April they approach it. The shape of the curve is peculiar to draw moss. The c.g.i. of heather is also low, and the curve has a sharp rise from July-August, a feature peculiar to heather.

There are very wide differences in the average c.g.i.-s of the swards but it is felt that no useful discussion can be based on them. They are averages struck between periods of the year which are dissimilar and in which the reasons for the sheep's preference for different swards change. They are, however, useful in a comparison among areas of the same type of sward and have been used for this purpose.

A discussion which arises out of a consideration of these facts is included in the discussion of sheep as a factor in the ecology of hill pastures.

Sheep as a factor in the ecology of hill pastures

Grazing is a dynamic factor in both changing and stabilising plant communities. The different responses of species to defoliation, treading and manuring lead to the suppression of some species and the encouragement of others. What is discussed here is not the effect of sheep on particular species, but their long-term effect on the hill pasture viewed as a whole.

Sheep will affect the vegetation of hill pastures by:-

- (a) their effect on particular plants and plant communities.
 - (b) causing a disproportion to occur between the amount grazed and the manurial return on different swards and different localities of the pasture.
 - (c) the movement of produce i.e. lambs, wool, off the hill.
 - (d) the concentration of grazing in localities for reasons other than the attractions of the swards found in that locality e.g. concentrations arising from local climatic differences.
 - (e) their reactions to particular plants e.g. their avoidance of bracken.
- a) The effect of sheep grazing on particular plants and plant communities

Some plants are suppressed by close grazing, others are encouraged. Of the dominant species found at Overshiels the following are encouraged:-

Agrostis spp., Festuca spp., T. repens, C. cristatus, and H. lanatus, and those suppressed:- heather,

molinia and nardus. Depending upon the management and the edaphic conditions, one or more of the species, /

in the two classes, becomes dominant.

The effect, however, depends not only on the intensity of grazing but also on the time at which it takes place during the seasonal growth of the plant. It has been shown that the highest comparative grazing intensities occur on the inferior swards during the period of least growth, and it is in this period that they are least affected by grazing. During periods of active growth, in spring and early summer, the inferior swards are ignored by the sheep, who have at this time an abundance of grazing on the superior swards. The effect of sheep grazing is to further the dominance of the inferior species while excessive grazing, particularly in early spring and summer, impoverishes the superior swards.

The operation of this relationship, over the course of centuries and on the basis of an initial edaphic and topographic differentiation between areas, has led to the development of swards sharply defined and localised on the hill pasture.

(b) The disproportion between the amount grazed and the manurial return

Sheep graze more during the day than during the night, and under many hill conditions they use one area for grazing and another for resting. As a consequence the manurial return is deficient in the grazing areas and excessive in the resting areas. No quantitative data can be given for this phenomenon except the observation of Crofton, that dung pellets were twenty times more numerous in the night camping /

areas than on the grazing areas, (47), and Sears's finding that lowland sheep took 60% of their total feed during the day but excreted only 40% of their dung and urine (49). The striking effect which disproportion in the manurial return has on the productivity of a sward has been shown by Sears and Goodall (48), and Sears also realises the long-term effect of fertility transference on hill pastures in New Zealand (49).

Fertility is carried in the dung from the superior to the inferior swards. It is sometimes argued that hill grazings can be improved by giving intensive manurial dressings to small areas and allowing the sheep to spread the manure over the pasture in their dung. The reasoning behind this idea is mistaken. The greatest transference of fertility will take place in the winter months, at which time the inferior swards, sited on the low ground, attain their highest comparative grazing intensities. This fertility will aid the un-eaten summer growth of the inferior species. In addition there will be a transference of fertility to the high ground ungrazed areas of the pasture. In effect the fertility will be dispersed and dissipated over the pasture and the only noticeable change will be the regression of the improved areas.

These remarks should not be understood as a criticism of the system of complementary grazing, for indeed they do not refer to this system. What is /

criticised is the attempt to improve hill pastures while taking no steps to control grazing.

(c) The movement of produce off the hill

Orr and Frazer (29) have pointed to the continual drain of lime and phosphorus, from the hill pastures, caused by the sale of stock reared on them. In the County of Argyll the annual loss, they calculated, is in the region of 35 tons of each mineral (CaO & P₂O₅). This is slight, but over a century, from an area already deficient in these minerals the loss is, "an impoverishment which cannot be ignored."

(d) The concentration of grazing in sheltered areas

Griffith & Hutton (78) found that lambs wintered on improved pasture, which was located on an exposed area, became sluggish and stiff during periods of exceptionally cold weather. Where there were areas of improved pasture on all the aspects of the hill, the sheep invariably grazed those sheltered from the wind.

It is the writer's observation that sheep are most sensitive to exposure in the spring, and hence the effect this has in determining the location of grazing will be greatest at this time of year, the time at which plant growth begins.

Localities which have a good soil, but are exposed, will not be grazed to the same extent as the sheltered areas and hence will carry an inferior sward.

The sheep's preference for a sunlit slope will /

be another factor in restricting grazing to certain areas, and will lead to under-grazing of the northern slopes.

Increased exposure at higher altitudes will result in the high ground being grazed to a lesser degree than the low ground. Thus the prevalence of inferior swards on the high ground, while due principally to edaphic factors, will be encouraged by the distribution of grazing.

(e) The avoidance of bracken by the sheep

There is good reason to believe that bracken is spreading rapidly over much of the hill pastures. The causes of this are obscure. What is clear, is that it suffers no check from grazing. The direct and indirect effects of bracken infestation have already been discussed. In short it reduces the total available grazing, decreases the proportion available in winter and probably encourages the dominance of inferior species.

If we consider the sum of the different effects of sheep on hill pastures, the essence of the relationship is as follows.

In the course of years of practice a balance between stocking rate and nutritional supply has been struck. On one side this balance is affected by social-economic factors having an influence on stocking rates, and on the other by the continuing effect the sheep have on the pasture. At best that continuing effect maintains the pasture at its present level of /

production, but change, where and when it takes place, and as it is effected by the sheep, is towards lower levels of productivity.

Sheep Behaviour

Stapledon and Jones (50) first drew the attention of workers in this country to the importance of animal behaviour studies and, since then, interest in this subject has steadily developed.

In the main the work has been descriptive, dealing with the proportion of the day the animal devotes to such activities as grazing, ruminating, and resting; the occurrence and sequence of these activities throughout the day, and the seasonal variations in them. It is thought that an understanding of the animal's behaviour will be an aid to the more efficient utilisation of pasture and at least one writer has attempted to draw conclusions, of suggested practical application, from his observations (51).

Behaviour studies have also been made as an aid to the solution of specific problems e.g. increasing the cow's appetite for bulky foods, (52) milk taints (53), conserving energy under conditions of severe drought (54), and suggested as an aid to the study of problems of helminth infestation (55).

Tribe and Gordon (57) and Tribe (56) have studied the importance of the sense of smell and vision in sheep, believing that studies in sensory perception are a "necessary forerunner to a critical study of its general behaviour."

The work has been reviewed by Tribe (73), Castle et al. (58), and Hughes and Reid (59), while Hancock has summarised criticisms of the experimental technique used by previous investigators (60).

The following features of animal behaviour have emerged from work on this subject.

Tribe (72) found the behaviour of individual sheep to be similar to that of the flock as a whole, a conclusion questioned by Ivins in the case of cattle (61), and the case of both cattle and sheep by Hughes and Reid (59), who found considerable individual variation about the flock and herd average.

According to Waite et al. (62), Castle et al. (58), Atkeyson et al. (63), and Hancock (60) the amount of time spent grazing by cattle increases as the pasture deteriorates; the contrary opinion is held by Johnstone-Wallace (64) who found that a herd of beef cows spent a constant proportion of their time grazing, irrespective of the stage of growth of the pasture. In view of the volume of contrary evidence the experience of Johnstone-Wallace must be regarded as exceptional, and indeed the small sample upon which he based his conclusions has been criticised in the light of further work.

Tribe (72) and Hughes and Reid (59) found little seasonal variation in the time spent grazing by sheep, although the latter workers found it to be slightly lower in winter.

There is a marked periodicity in grazing during the hours of daylight (72), which is related to sunrise and sunset (59, 62, 58, and 65), but no marked periodicity during the hours of darkness.

In the temperate climatic zone, grazing is concentrated during the hours of daylight and its /

intensity is affected by the day-length and probably by the temperature. Cattle and sheep will graze very lightly, or not at all, during the short summer nights, but do so during the long winter ones (59, 62), and during the long day-lengths of summer the intensity of grazing is much less than in the short day-lengths of winter.

Behaviour, in relation to climatic factors, has not been critically studied in the temperate zone, but for obvious reasons has occupied the attentions of workers in tropical and semi-tropical zones. Bosman (66) has studied the effect of high temperatures on the behaviour of sheep, and found that the sheep tend to restrict grazing to the cooler parts of the day. In the high summer temperatures of Louisiana, U.S.A., dairy cows do much of their grazing during the night and considerable differences among breeds in their heat tolerance were found. The physiological basis of heat tolerance is being studied at the Hannah Dairy Institute (69) and other workers have shown the deleterious effect of high temperatures on spermatogenesis in sheep (70). One of the most interesting observations is that of Hancock (60) who found the behaviour of monozygotic twin calves to be similar. That behaviour patterns are inherited has a very important implication in the breeding of hill sheep. Under hill conditions the behaviour of the sheep in winter may make the difference between survival and death. The use of tups reared off the /

hill, whose behaviour under hill conditions has never been severely tested, is therefore questionable.

The Behaviour of Hill Sheep

No behaviour studies of hill sheep, in the restricted sense of the study of the proportion of the day devoted to different activities, have been published, although Boulet apparently made such observations. He does not, however, publish them in his thesis (32).

Boulet discusses the behaviour of the sheep in relation to rain, strong cold winds, insolation, and their "daily routine."

Welsh Mountain sheep are sensitive to changes in the weather. Their normal grazing behaviour is upset by rain, cold winds make them seek shelter and they congregate on the sun-exposed southern slopes, especially in the forenoon. The flock as a whole has a daily sequence of activities, using the rougher swards at either end of the day and using more or less the same night camping areas. On wet days they graze the rough herbage more than on dry days. They appear to have an intimate knowledge of their own hill pasture, knowing where to go at different times of the year for a palatable "bite."

Observations on Sheep Behaviour at Overshiels

(a) General observations

(1) Behaviour in relation to rain

When the rain was heavy and driving the sheep stopped grazing and stood up facing away from it. /

After a night of rain, followed by a damp humid morning, they were late in beginning to graze. In such conditions they would not begin to graze until a short time after sunrise: normally they begin to graze before it. They were not observed to utilise the rougher types of vegetation to a greater extent when they were damp.

(2) Behaviour in relation to exposure

Sheep are sensitive to exposure but this sensitivity appears to be more acute at certain times of the year. During winter they will continue to graze under all conditions except those approaching a blizzard. In spring, and during lambing time, they are much more sensitive to exposure and seek shelter under conditions of exposure to which they would not have reacted a month or so before. Indeed, it was only during lambing time, and for a month or so afterwards, that behaviour which could be surmised to be due to exposure, was noted. No departure from their normal routine was noted at other times of the year, which, it was thought, could be attributed to the weather.

(3) The sheep's knowledge of its own hill pasture

That this knowledge exists is something which the writer thinks is indisputable, and the following instances are given as evidences of it.

In the period December-February the sheep were often observed at first light to be on the low ground, where they were grazing the agrostis-fescue sward. This was covered with hoar frost which persisted /

when the sun rose because the area lay in the shadow. The area in the vicinity of the round stell was not in the shadow and the hoar frost did not persist there. This the sheep appeared to know, for when the sun rose they immediately moved from the hollow to the high ground. The sheep could not see the sun on the high ground from where they were, but they knew the correct course of action was to move up the hill.

At the time when the sheep were grazing the young heather they were often seen at first light south of the round stell. In spite of the fact that they could not see the young heather areas from where they had camped during the night, (and they did not camp in the same place every night) they moved in a straight line towards the heather. This presumes, not only a knowledge of the type of sward they wished to graze, but also its exact direction from where they had rested for the night.

(4) Daily grazing routine and its seasonal variation

In the period January-February the sheep tend to keep to their low ground at all times of the day and go to the high ground only when the weather is open. From April to September they rest at night on the high ground, moving up, or being moved up by the shepherd, about 1700 or 1900 hours. There they graze and rest, principally rest, until they move down to the low ground before sunrise. It is only in this period, April-September, that they are closely herded; at other times of the year the shepherd /

preferred the sheep to find their own grazing. From October to December they tend to remain on the high ground throughout the whole day. Boulet remarks that the sheep graze their night camping areas from October onwards. If these night camping areas were sited on the high ground it may be that Boulet is recording what the present writer calls a location effect, and that the sheep graze their night camping areas in the last quarter of the year because they tend to remain on the high ground where these are sited. This was certainly what happened at Overshiels.

(5) Periods of rest during the hours of daylight

At each hourly observation, the total number of sheep and the number lying down was noted. This latter figure was then calculated as a percentage of the total.

If the primary object of this study had been sheep behaviour, then the method of collecting the data would be open to severe criticism, the animals being observed neither continuously nor at night.

However, as the results are of interest, they are presented with the above reservations on the method of observation.

Average percentage of sheep resting during
daylight hours (period Sept. 1950-Sept. 52)

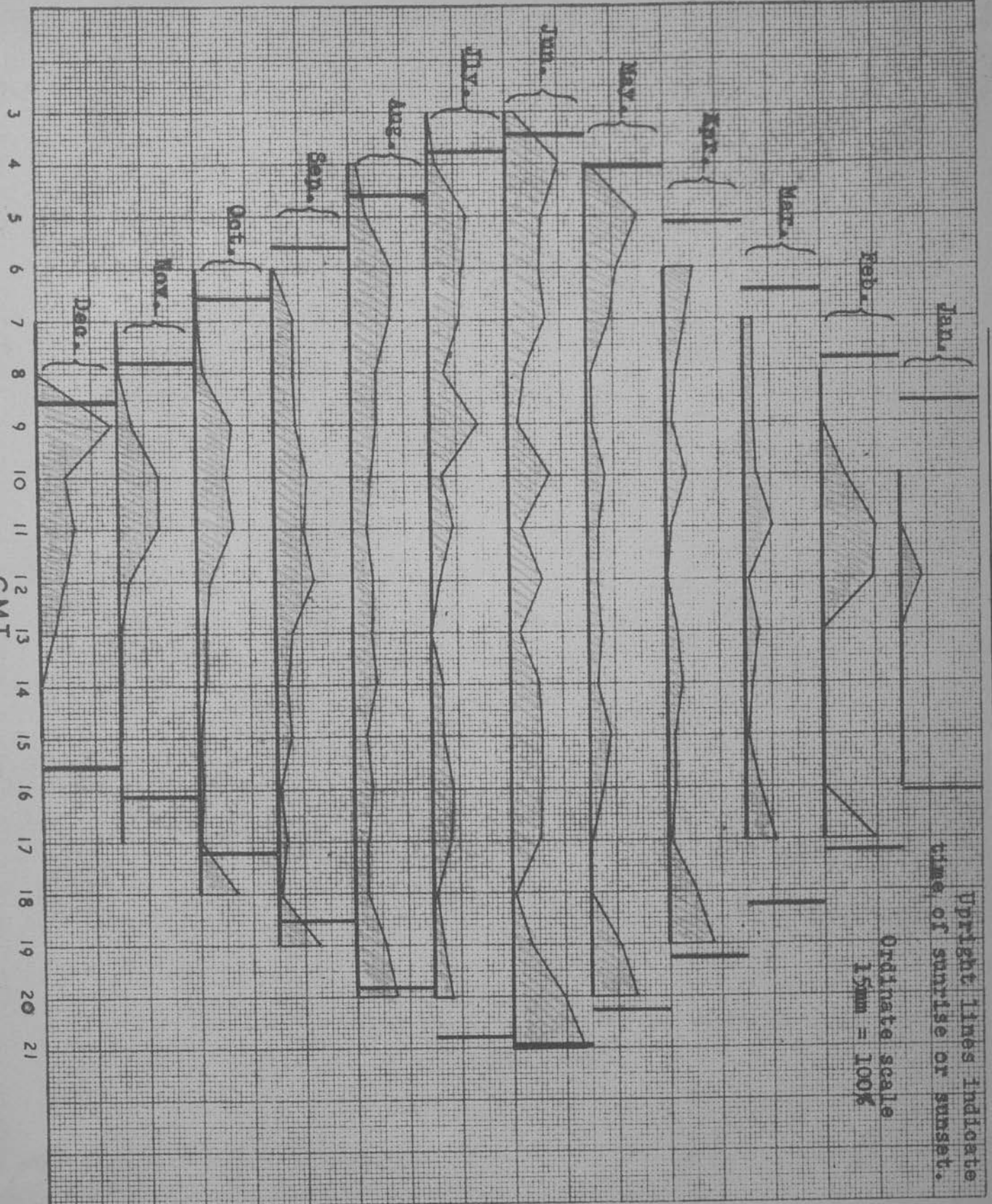
G.M.T. (hrs.)	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Jan.								0	0	25	0	0	0	0					
Feb.						0	2	30	68	67	0	0	0	0	58				
Mar.					9	9	8	14	37	7	15	8	5	15	37				
Apr.				36	25	13	8	26	5	0	13	20	7	8	4	36	55		
May		5	64	41	31	6	5	21	10	10	15	10	26	17	1	0	36	54	
June	10	66	42	41	48	21	13	52	14	40	12	36	40	37	34	2	21	65	88
July	2	9	52	43	40	20	60	15	29	12	3	14	14	25	22	7	11	22	
Aug.		10	20	54	51	30	30	22	18	27	25	30	16	21	16	15	35	50	
Sept.				0	24	25	27	41	36	48	21	14	18	5	9	3	50		
Oct.				0	0	8	45	38	45	16	12	7	1	2	0	45			
Nov.					0	1	15	52	54	14	4	2	0	0	0				
Dec.					0	0	89	33	44	30	16	0	0						

These values are plotted on graph No. 17, which also shows the times of sunrise and sunset on the 14th day of each month.

Periods of rest are related to the times of sunrise and sunset in the long days of the period April to September. The sheep begin to move from the high ground before sunrise, and after a period of grazing in the course of moving to and after arriving at the low ground, they rest. They rest for one or two hours then begin to graze again. There is another, less general period of rest in the afternoon, less general in the sense that the sheep do not all rest at approximately the same time. In the late afternoon the sheep move up the hill and begin to settle down shortly before sunset.

No observations were made at night, but Crofton (71) remarks, that hill sheep move and graze very little at night. Of the sheep observed by him, during daylight 90% were grazing, while only 10% were grazing at night. Wallace noted that hill sheep do not graze /

Periods of Rest During Hours of Daylight.



during the short summer nights but do so between the hours of 11 p.m. and 2 a.m. during the long winter nights (14).

No evident periodicity in resting emerges from these figures, but it is unlikely this would be clearly noted unless observations were made on the behaviour of individual sheep.

During the short days, from October-March, the sheep rest much less than in the long days of summer and only one general period of rest occurs. This takes place before mid-day, and according to the day-length, at some time between 0900 and 1200 hours.

Comparing months occurring in the first and second halves of the year and having similar day-lengths, e.g. March-May and August-October, it is seen that rest in daylight is much less in the first half of the year. This behaviour is perhaps related to the differences in available grazing and temperature between these periods.

It will be remembered that the spring of 1951 was much more severe than that of 1952 and that grazing was also more scarce in the former year. It is therefore interesting to note, that the average number of sheep resting in the daylight hours of April was 4%, and of May 8%, in 1951, while the corresponding figures for 1952 were 17% and 18%.

Hill sheep are much more active during the hours of daylight than lowland sheep. The table below shows the comparison between the average times spent resting during the hours 0700-1900, in the months April- /

September by sheep under lowland conditions (figures adapted from Tribe (72)) and the sheep at Overshiels.

Average percentage time spent resting in the hours 0700-1900.

	Apr.	May	June	July	Aug.	Sept.
Tribe (lowland)	32	32	40	45	45	47
Overshiels	14	13	29	21	26	23

Only in July do the hill sheep rest more than the sheep under the conditions of Tribe's observations.

Grazing Behaviour and Helminthiasis

Morgan et al. (74) have shown that the marked spring rise in worm egg counts is due to an increased worm burden and not to an increased egg production by helminths which have over-wintered in the sheep.

The increased worm burden can arise from either an increased stocking rate or the activation of larvae in the soil or grass mat; or what is more likely - a combination of these events. The period of highest infestation lies between the first week of March and the end of May. Grazing was most concentrated at Overshiels in January-February and remained at a high level until the sheep began to graze the bracken sward in the middle of April. There is a further decline in the concentration of grazing from the middle of June onwards when the sheep begin to use the heather sward. The concentration in March and the early part of April is on the clovery flush grass sward and Taylor has pointed out that clover may aid nematode infestation (55).

There is therefore a decline in the concentration /

of grazing from the early spring onwards which is offset to a certain extent by the increase in stocking rate when the lambs begin to graze. It is doubtful, however, if the lambs can have any great effect in increasing the infective larval population before the middle of July. In the last quarter of the year, when the sheep change their general location of grazing to the high ground, they are on ground which is comparatively fresh, though local concentrations of infective larvae can be expected on the night camping areas. By November-December the soil temperatures begin to fall below the threshold value for the activation of most larvae (circa 50°F).

While the stocking rate does not determine the degree of helminth infestation, it certainly does affect it, and at Overshiels, and presumably on many hill pastures, the behaviour of the sheep would encourage a high spring infestation. If the degree of concentration of grazing were the only factor determining infestation we should expect it to decline as the season advances. This is especially so when we remember that the sheep are extending their grazing range to include swards which they had almost completely avoided in the immediately preceding period, i.e. young heather.

The findings of Morgan et al. are not at variance with what might be expected from the behaviour of the sheep. The causation of helminth infestation, however, is so complex, that no exact correlation between behaviour and infestation can be expected.

The relation of grazing intensity and tick (Ixodes ricinus) count on different swards.

Tick counts vary between swards and the question that arises is whether this is due to differences in the grazing intensity, or to differences in the micro-climate between swards which result in good development of the tick in some, and partial suppression in others. The relatively low tick count in old heather may be due to a low grazing intensity or to the micro-climate below a heather canopy being unsuitable for the development of the tick.

Campbell planted young ticks on different swards and found their development to proceed favourably on all (75). He therefore discounts the respective micro-climates of the swards as the reason for the variation in their tick count, and suggests that differences in grazing intensity (= stocking rate) are the correct explanation.

In this connection it is of interest to compare the relative tick count and grazing intensity during the tick season (March-June) on three typical hill swards. The tick counts are those of Campbell.

Sward Type	Comparative tick count	Comparative grazing intensity
Agrostis-fescue flush with Juncus	100	100
Agrostis-fescue invaded by bracken	70-100	55
Old climax heather	0	7

This table indicates that tick count is related to the grazing intensity on a sward.

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BOTANICAL ANALYSIS - BRACKEN SWARD

Table I

No. of Botanical Analysis		1	3	5a	5b	5c	5*	6	8	9	10	11d	11c	11a	11e	11b	11*		
Found only in the Bracken	<i>Polygala vulgaris</i> L.	-	T	-	-	T	T	-	1	-	-	-	-	-	-	-	-	-	
	<i>Fragaria vesca</i> L.	-	-	-	-	T	T	-	T	1	-	T	-	-	-	-	-	T	
	<i>Euphrasia officinalis</i> agg.	-	-	-	-	1	T	-	-	-	-	-	-	-	-	-	-	-	
	<i>Achillea millefolium</i> L.	T	-	-	T	1	1	-	-	-	-	1	T	-	T	T	T	T	
	<i>Lotus corniculatus</i> L.	-	-	-	1	T	T	-	-	-	-	-	-	-	-	-	-	-	-
	<i>Urtica dioica</i> L.	-	-	-	-	T	T	-	-	-	-	-	-	-	-	-	-	-	-
	<i>Oxalis acetosella</i> L.	-	-	T	1	1	1	-	1	-	-	T	1	1	1	1	1	1	1
	<i>Veronica officinalis</i> L.	-	1	T	T	-	T	-	1	-	-	-	-	-	T	-	1	T	T
	<i>Veronica montana</i> L.	-	T	-	-	-	-	-	T	-	-	-	-	-	T	-	-	-	T
	<i>Campanula rotundifolia</i> L.	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	T
	<i>Thymus serpyllum</i> agg.	-	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	<i>Filipendula ulmaria</i> (L.) Maxim.	-	-	-	-	-	-	-	-	-	T	-	-	-	-	-	-	-	-
	<i>Ophioglossum vulgatum</i> (L.)	-	-	-	-	T	T	-	-	-	-	-	-	-	-	-	-	-	-
	<i>Plantago lanceolata</i> (L.)	-	-	-	1	T	T	-	-	-	-	-	-	-	-	-	-	-	-
<i>Poa annua</i> L.	-	-	-	-	T	T	-	1	-	1	1	-	-	1	T	T	T		
Gramineae	<i>Poa pratensis</i> L.	1	2	2	2	4	3	1	1	2	-	4	2	2	1	3	3	3	
	<i>Festuca rubra</i> L.	2	3	3	2	2	2	2	3	2	1	2	1	2	1	2	2	2	
	<i>Festuca ovina</i> L.	2	5	4	4	1	3	3	2	-	1	2	2	2	1	3	2	2	
	<i>Agrostis tenuis</i> Sibth.	5	5	5	5	4	5	5	5	5	3	5	4	5	4	5	5	5	
	<i>Agrostis canina</i> L.	3	2	1	1	1	1	3	4	3	4	1	3	2	1	1	2	2	
	<i>Agrostis stolonifera</i> L.	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	T	
	<i>Anthoxanthum odoratum</i> L.	2	1	2	3	2	2	-	3	2	2	3	2	4	3	-	-	2	
	<i>Deschampsia caespitosa</i> (L.) Beauv.	1	T	-	1	1	1	-	-	T	-	-	-	-	-	-	-	-	
	<i>Deschampsia flexuosa</i> (L.) Trin.	-	-	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	
	<i>Sieglingia decumbens</i> (L.) Bernh.	-	T	-	-	-	-	-	-	-	T	-	-	-	T	-	-	T	
	<i>Holcus lanatus</i> L.	2	2	1	1	2	1	1	1	1	T	T	-	-	-	-	1	T	
	<i>Holcus mollis</i> L.	2	-	1	-	-	1	1	-	1	1	-	1	T	1	-	-	1	
	<i>Nardus stricta</i> L.	T	1	1	-	1	1	1	1	1	1	1	-	-	-	-	1	1	
	<i>Molinia caerulea</i> (L.) Moench.	T	1	1	1	-	1	1	-	-	T	1	1	-	1	-	-	1	
<i>Cynosurus cristatus</i> L.	-	T	-	-	T	T	-	-	-	-	1	-	-	-	T	-	T		
Miscellaneous Species	<i>Trifolium repens</i> L.	1	2	1	2	2	2	-	1	T	-	2	1	2	1	T	1	1	
	<i>Ranunculus repens</i> L.	2	1	T	T	2	1	T	1	1	-	1	-	1	-	-	-	1	
	<i>Cerastium vulgatum</i> L.	1	T	-	1	T	T	T	1	1	-	1	-	1	T	-	-	T	
	<i>Viola</i> spp.	-	1	T	1	1	1	-	1	T	-	1	1	1	-	-	-	T	
	<i>Cardamine pratensis</i> L.	-	-	-	-	T	T	-	-	T	-	-	-	-	-	-	-	-	
	<i>Veronica serpyllifolia</i> L.	-	T	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	
	<i>Lathyrus montanus</i> (L.) Bernh.	-	-	-	-	-	-	-	-	1	-	T	T	-	T	-	-	T	
	<i>Sagina procumbens</i> L.	-	T	-	-	-	-	-	-	T	-	-	-	-	-	-	-	-	
	<i>Leontodon autumnalis</i> L.	-	-	T	-	T	-	-	-	-	-	-	-	-	-	-	-	-	
	<i>Prunella vulgaris</i> L.	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	T	
	<i>Cirsium arvense</i> (L.) Scop.	-	T	-	-	T	T	-	-	-	-	-	-	-	-	-	-	-	
	<i>Cirsium vulgare</i> (Savi) Ten.	-	-	-	-	-	-	-	-	-	T	-	-	-	-	-	-	-	
	<i>Luzula</i> spp.	1	2	1	2	1	2	2	1	1	2	2	2	3	1	4	2	2	
	<i>Carex panicea</i> (L.)	T	1	-	-	-	-	-	T	-	-	-	-	-	1	-	-	T	
	<i>Carex</i> spp.	1	1	2	2	1	1	1	1	1	1	1	1	1	-	1	1	1	
	<i>Juncus communis</i> agg.	1	-	-	-	-	-	-	T	1	-	-	-	-	-	-	-	-	
	<i>Calluna vulgaris</i> L.	-	-	1	1	-	T	1	-	-	-	-	-	-	-	-	-	T	
	<i>Vaccinium myrtillus</i> L.	-	-	T	1	-	T	1	-	-	-	-	T	-	-	-	-	T	
	<i>Potentilla erecta</i> (L.) Rausch.	1	2	2	2	1	1	1	2	1	3	-	2	2	-	1	1	1	
	<i>Galium hercynicum</i> Weigel.	2	1	2	2	1	1	3	3	1	4	1	3	2	2	2	2	2	
<i>Rumex acetosa</i> L.	T	T	-	T	T	T	1	-	T	T	1	1	1	1	1	1	1		
<i>Blechnum spicant</i> , L.	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	T		

Table II

No. of botanical analysis		Molinia Sward					Grass Sward							
		14	15	16	17	19	22	23b	23a	23*	24e	24b	24a	24*
Found only in Grass Sward	<i>Achillea ptarmica</i> L.	-	-	-	-	-	-	-	-	-	-	-	T	T
	<i>Taraxacum officinale</i> agg.	-	-	-	-	-	-	-	-	T	-	-	-	T
	<i>Cirsium palustre</i> (L.) Scop.	-	-	-	-	-	-	1	-	T	-	T	2	1
	<i>Juncus articulatus</i> L.	-	-	-	-	-	-	-	-	-	T	T	1	T
	<i>Equisetum palustre</i> L.	-	-	-	-	-	-	-	-	-	-	-	T	T
	<i>Briza media</i> L.	-	-	-	-	-	-	T	-	T	-	-	T	T
Gramineae	<i>Poa pratensis</i> L.	-	-	-	-	-	-	T	T	T	1	1	1	1
	<i>Festuca rubra</i> L.	1	-	1	-	-	-	3	2	3	2	2	3	2
	<i>Festuca ovina</i> L.	3	1	2	3	4	5	2	3	3	2	3	T	2
	<i>Agrostis tenuis</i> Sibth.	1	-	1	-	-	4	5	4	4	2	4	4	3
	<i>Agrostis canina</i> L.	1	-	1	-	T	2	1	3	2	3	2	1	2
	<i>Agrostis stolonifera</i> L.	-	-	-	-	-	T	-	-	-	-	1	1	1
	<i>Anthoxanthum odoratum</i> L.	1	-	T	T	1	1	3	2	2	5	3	3	4
	<i>Deschampsia caespitosa</i> (L.) Beauv.	-	-	-	-	-	1	-	1	1	1	-	1	1
	<i>Sieglingia decumbens</i> (L.) Bernh.	-	-	-	-	-	T	-	-	-	-	-	T	T
	<i>Holcus lanatus</i> L.	1	-	T	-	-	T	5	3	4	5	3	5	4
	<i>Holcus mollis</i> L.	1	-	-	-	-	-	-	-	-	-	1	-	1
	<i>Nardus stricta</i> L.	2	1	1	1	3	4	4	4	4	3	4	2	3
	<i>Molinia caerulea</i> (L.) Moench.	5	5	5	5	5	T	1	1	1	T	-	-	T
	<i>Cynosurus cristatus</i> (L.)	-	-	-	-	-	-	T	-	T	1	1	1	1
	<i>Deschampsia flexuosa</i> (L.) Trin.	1	2	1	2	2	T	-	T	T	1	-	1	1
Miscellaneous	<i>Trifolium repens</i> L.	-	-	-	-	-	-	2	3	2	2	3	4	3
	<i>Ranunculus repens</i> L.	-	-	-	-	-	-	1	1	1	2	1	3	2
	<i>Cerastium vulgatum</i> L.	-	-	-	-	-	-	1	-	1	1	1	T	1
	<i>Viola</i> spp.	1	-	-	-	-	-	-	T	T	-	-	T	T
	<i>Veronica serpyllifolia</i> L.	-	-	-	-	-	-	T	-	T	-	-	-	-
	<i>Cardamine pratensis</i> L.	-	-	-	-	-	-	-	-	-	T	1	-	T
	<i>Lathyrus montanus</i> (L.) Bernh.	-	-	-	-	-	-	-	1	1	1	T	-	T
	<i>Sagina procumbens</i> L.	-	-	-	-	-	-	T	-	T	-	-	-	-
	<i>Leontodon autumnalis</i> L.	-	-	-	-	-	-	T	-	T	T	T	-	T
	<i>Prunella vulgaris</i> L.	-	-	-	-	-	-	-	-	-	-	-	1	1
	<i>Cirsium arvense</i> (L.) Scop.	-	-	-	-	-	-	T	-	T	T	-	-	T
	<i>Cirsium vulgare</i> (Savi) Ten.	-	-	-	-	-	-	-	-	-	-	-	1	T
	<i>Luzula</i> spp.	-	-	-	-	1	2	T	2	1	1	1	1	1
	<i>Carex panicea</i> (L.)	1	-	1	-	-	1	1	2	1	4	2	3	3
	<i>Carex</i> spp.	T	-	1	T	-	T	3	2	3	2	1	2	2
	<i>Juncus communis</i> agg.	-	-	-	-	-	-	1	1	1	1	1	-	1
<i>Juncus squarrosus</i> L.	-	1	-	1	-	-	-	1	1	-	-	-	-	
<i>Calluna</i> /	-	-	-	-	-	-	-	-	-	-	-	-	-	

* mean frequency for areas 23 and 24 respectively

Table II
(continued)

	No. of botanical analysis		Molinia Sward					Grass Sward							
			14	15	16	17	19	22	23b	23a	23*	24e	24h	24a	24*
Miscellaneous	<i>Calluna vulgaris</i> L.	-	T	-	1	T	-	-	-	-	-	-	-	-	-
	<i>Erica tetralix</i> L.	-	-	-	T	-	-	-	-	-	-	-	-	-	-
	<i>Vaccinium myrtillus</i> L.	1	T	T	1	T	-	-	-	-	-	-	-	-	-
	<i>Vaccinium vitis-idaea</i> L.	-	-	-	1	-	-	-	-	-	-	-	-	-	-
	<i>Potentilla erecta</i> (L.) Rausch	T	1	1	1	1	2	2	2	2	1	1	T	1	1
	<i>Galium hercynicum</i> Weigel	1	T	1	T	1	1	1	-	-	1	1	-	1	1
	<i>Trichophorum caespitosum</i> (L.) Hartman	T	1	T	1	T	-	-	-	-	1	-	-	-	T
	<i>Rumex acetosa</i> L.	-	-	-	-	-	-	T	T	T	-	1	-	-	T

* mean frequency for areas 23 and 24 respectively

Table IV

No. of botanical analysis	Young Heather				Draw Moss Areas					Lea Heather		Old Heather											Burnt Winter 1951					
	32	33	34	4	54	47	48	50	46	42	43	41	53	45	55	44a	51	49	38	40	37	35	21	44	52	39	36	
	<i>Cryptogramma crista</i> Hook & Bauer	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Empetrum nigrum</i> L.	-	-	-	1	-	-	1	1	1	-	-	1	1	-	2	1	3	1	-	-	1	1	-	-	1	-	-	-
<i>Eriophorum vaginatum</i> L.	-	-	-	-	5	4	4	4	4	-	-	1	-	1	1	3	1	-	-	-	-	-	-	1	1	-	-	
<i>Eriophorum angustifolium</i> Honck.	-	-	1	-	2	5	2	1	2	-	-	-	1	5	2	1	4	4	-	-	-	-	-	2	1	-	-	
<i>Festuca ovina</i> L.	2	1	1	5	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	1	1	1	3	-	-	-	-	
<i>Agrostis tenuis</i> Sibth.	-	-	-	1	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Agrostis canina</i> L.	-	-	-	3	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Anthoxanthum odoratum</i> L.	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Deschampsia flexuosa</i> (L.) Trin.	5	5	3	3	1	-	-	-	-	5	3	4	-	2	-	3	1	1	1	5	4	3	4	3	-	3	4	
<i>Nardus stricta</i> L.	3	1	1	2	1	-	-	-	1	1	3	1	1	1	-	1	1	-	1	1	2	1	2	-	1	1	1	
<i>Molinia caerulea</i> (L.) Moench.	5	5	5	2	4	4	5	4	3	5	4	5	4	5	5	5	3	4	5	5	5	5	5	5	4	5	5	
<i>Luzula</i> spp.	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Carex</i> spp.	-	-	1	-	1	1	-	1	1	2	1	4	1	-	-	-	-	2	1	-	-	-	-	1	1	-	1	
<i>Juncus squarrosus</i> (L.)	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	1	-	-	-	2	1	-	-	-	-	-	
<i>Calluna vulgaris</i> L.	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	4	5	4	2	4	
<i>Erica tetralix</i> L.	-	-	1	-	-	-	1	-	1	-	-	1	1	-	2	-	2	1	-	-	1	-	1	-	1	-	-	
<i>Vaccinium myrtillus</i> L.	4	1	1	4	2	2	2	2	2	1	2	5	1	3	4	1	4	2	1	1	4	3	3	1	2	2	3	
<i>Vaccinium vitis-idaea</i> (L.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	
<i>Galium hercynicum</i> Weigel	-	-	-	2	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Trichophorum caespitosum</i> (L.) Hartman	-	-	1	-	1	-	1	-	1	-	1	2	1	-	1	-	1	-	-	-	1	1	-	-	1	-	-	
<i>Potentilla erecta</i> (L.) Rausch.	1	1	-	2	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	
<i>Lathyrus montanus</i> (L.) Bernh.	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Blechnum spicant</i> L.	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

Found
only on
Heather

Meteorological Data during Period of Observation

Data from Loan Meteorological Station, Lauder, (altitude 550 feet)
for period September 1950 - September 1952 inclusive

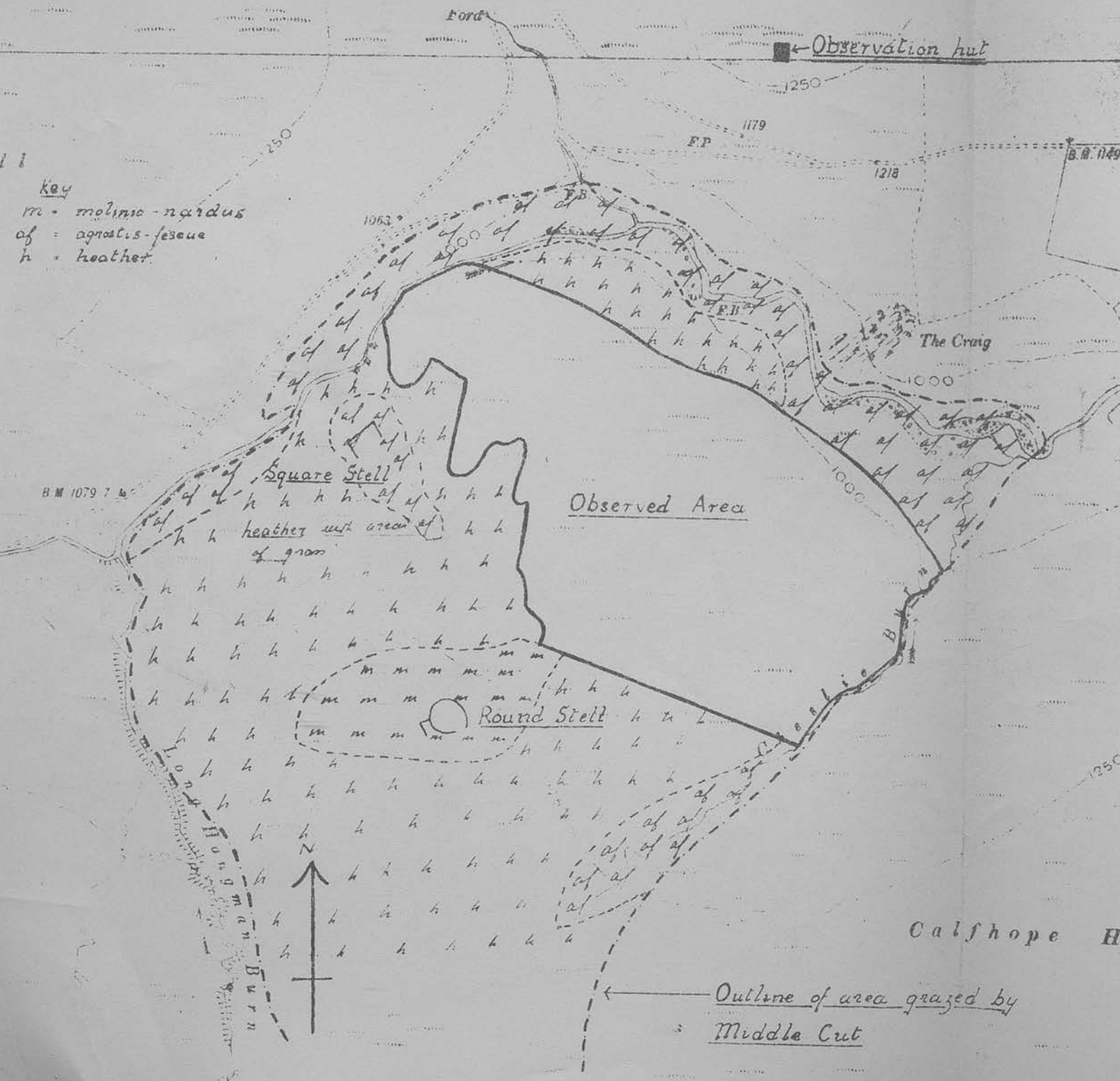
Month		Temperature			Rain in mms.	Snow lying at 0900 hrs	Hail
		Mean of Max. °F.	Mean of Min. °F.	Average of Max. and Min.			
September	1950	58.9	43.7	51.3	105.7	0	0
	1951	61.6	43.7	52.7	35.6	0	0
	1952	55.1	42.4	48.7	52.3	0	1
October	1950	53.1	39.4	46.3	42.4	0	1
	1951	55.0	39.9	47.5	8.6	0	0
November	1950	44.4	31.6	38.0	111.3	0	0
	1951	49.7	37.7	43.7	166.6	0	0
December	1950	36.3	25.6	30.9	51.8	23	0
	1951	44.8	33.0	38.9	54.4	1	1
January	1951	39.5	28.5	34.0	101.3	18	0
	1952	37.9	25.0	31.5	64.5	23	0
February	1951	40.3	29.3	34.8	63.8	6	0
	1952	43.5	30.8	37.1	11.7	5	0
March	1951	42.5	29.3	35.9	64.5	4	1
	1952	46.7	35.4	41.1	31.0	2	2
April	1951	48.4	33.2	40.8	62.0	1	1
	1952	55.7	37.0	46.3	33.3	0	0
May	1951	53.7	37.5	45.6	67.1	0	0
	1952	62.0	43.2	52.6	46.0	0	0
June	1951	62.8	42.6	52.7	27.4	0	0
	1952	62.7	45.7	54.2	52.6	0	0
July	1951	66.6	50.2	58.4	68.6	0	0
	1952	68.1	49.6	58.9	42.7	0	0
August	1951	63.1	47.0	55.1	86.4	0	0
	1952	65.4	49.2	57.3	88.4	0	0

APPENDIX CList of species mentioned in the Text

Common name/s and Latin name/s where the latter is different from that adopted by Clapham, Tutin and Warburg.	Nomenclature according to Clapham, Tutin and Warburg, "Flora of the British Isles" Camb. Univ. Press. 1952.
Blaeberry	<i>Vaccinium myrtillus</i> L.
Bog asphodel	<i>Narthecium ossifragum</i> (L) Huds.
Bracken	<i>Pteridium aquilinum</i> (L.) Kuhn.
Daisy	<i>Bellis perennis</i> L.
Deer hair, <i>Scirpus caespitosus</i>	<i>Trichophorum caespitosum</i> (L). Hartman.
Draw moss, cotton grass	<i>Eriophorum vaginatum</i> L.
Galium saxatile	<i>Galium hercynicum</i> Weigel.
Gorse	<i>Ulex europaeus</i> L.
Heath rush, stool bent	<i>Juncus squarrosus</i> L.
Heather, common heather	<i>Calluna vulgaris</i> (L) Hull
Molinia	<i>Molinia caerulea</i> (L) Moench.
Nardus, white bent	<i>Nardus stricta</i> L.
Ragwort	<i>Senecio jacobaea</i> L.
Self heal	<i>Prunella vulgaris</i> L.
Sorrel	<i>Rumex acetosella</i> agg.
Sheep's fescue	<i>Festuca ovina</i> agg.
Sow thistle	<i>Sonchus oleraceus</i> L.
Sweet vernal grass	<i>Anthoxanthum odoratum</i> L.
Triodia decumbens	<i>Sieglingia decumbens</i> (L) Bernh.
Wild pansy	<i>Viola tricolor</i> L.
Wood rush	<i>Luzula sylvatica</i> (Huds.) Gaud.
Yarrow	<i>Achillea millefolium</i> L.

Part of Overshiels Farm, Fountainhall.

Enlarged from Ordnance Survey, Midlothian XXIII N.W. & S.W. Scale = 4.2 inches/mile.



key
 m = *molinia-nardus*
 af = *agrostis-fesoue*
 h = heather

Square Stell

Observed Area

Round Stell

Tons of Honoman Burn



← Outline of area grazed by Middle Cut

Calshope H

The Craig

Ford

← Observation hut

B.M. 1079 7

B.M. 1149

1179

1218

1063

1250

1000

1000

1250

FP

EB

EB

B

R

B

R

B

R

B

R

B

R

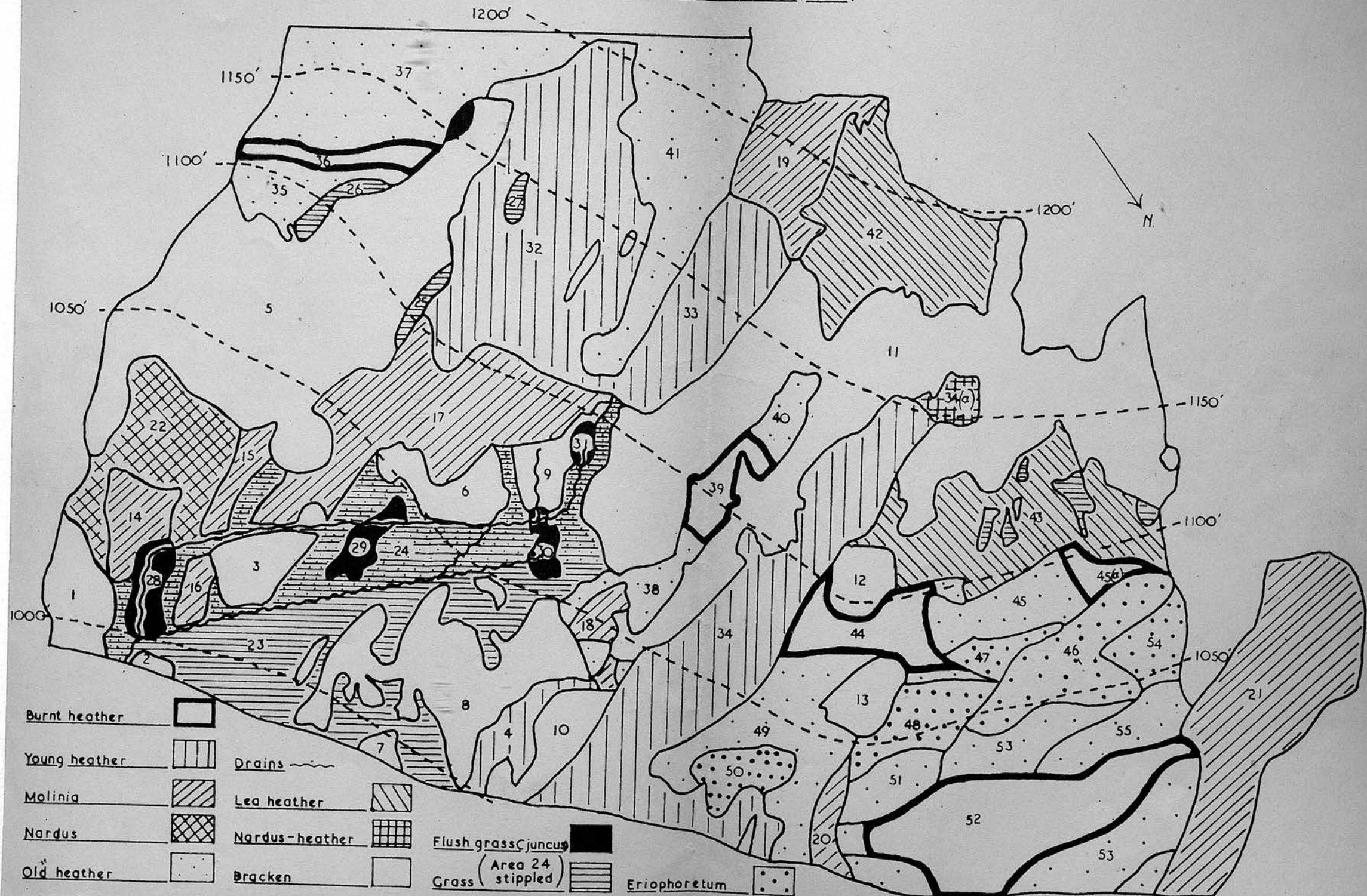
B

R

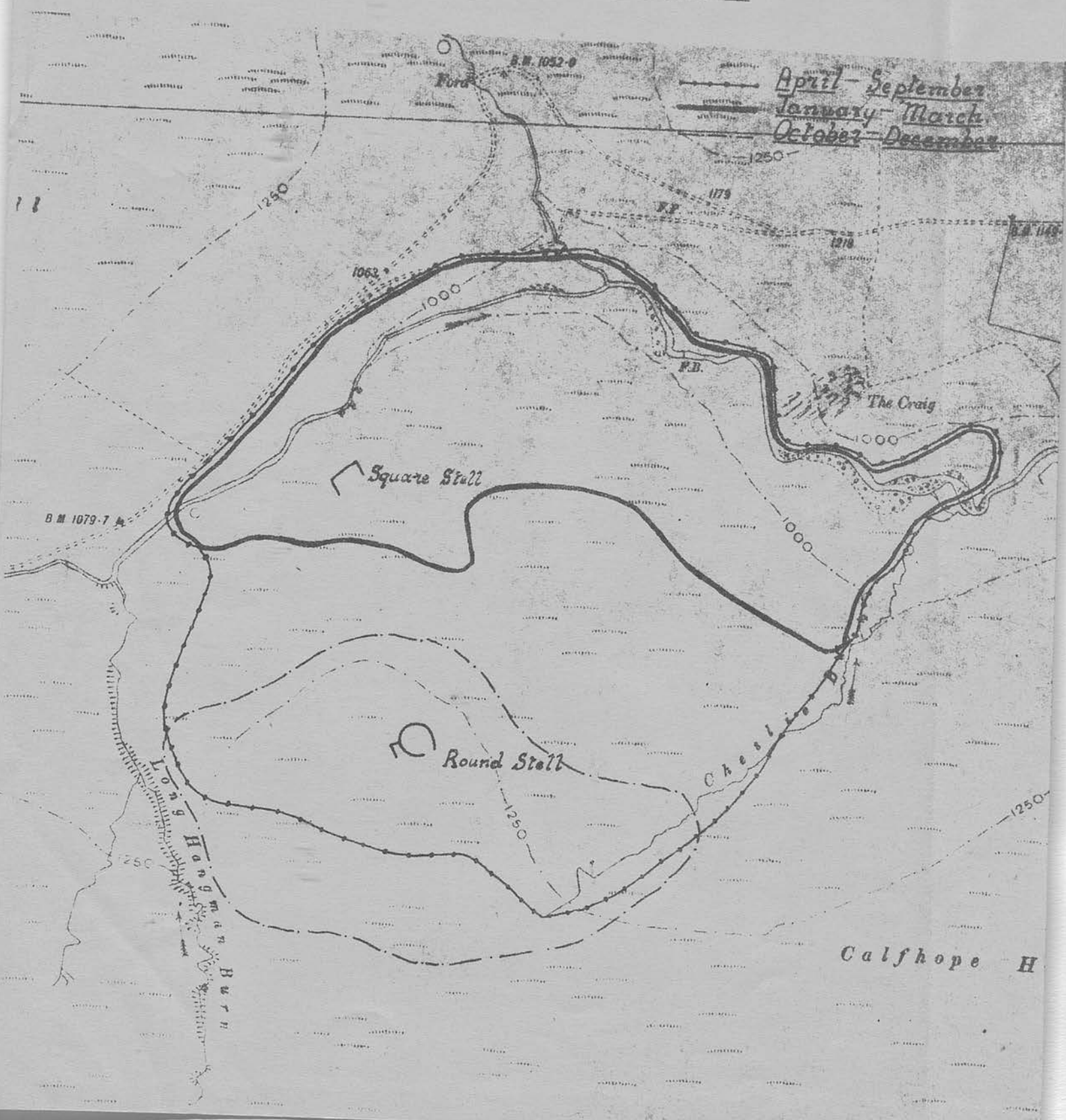
B

MAP No. 2

Scale 1 inch = 210 feet (approx.)



Seasonal Variation in Grazing Location



MAP No. 4

Location of botanical analyses

