COMPARISONS OF THE LIFE HISTORIES OF DIFFERENT VARIETIES OF MITOPUS MORIO (ARACHNIDA : OPILIONES)

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C O N T E N T S

I

INTRODUCTION

INTRODUCTION

During zoological studies on the Moor House National Nature Reserve one species of harvestman (Arachnida, Opiliones) was found to be very common on several sites during the summer.

This species Mitopus morio (Fabricius), is probably the most common of British harvestmen. It has been recorded from almost all counties of the British Isles, many islands, including the Isle of Wight, Skokholm, Rum, St. Kilda, Orkneys and Shetlands, and also from the summits of several of the highest mountains such as Snowdon, Snaefell, Ben Cruachan and Mount Leinster. (Bristowe. 1949)

Outside Britain it occurs through North America, China, Siberia, Persia, North Africa and the whole of Europe from the Mediterranean to the far North, including the whole of Iceland, Spitzbergen, the west coast of Greenland up to 73°28' and the east coast at least as far as 63°N.

Besides the temperate grasslands and forests it has been found in the quite sterile alpine zone, under seaweed on the shore, near hot springs and in very dry areas. (Henriksen. 1938)

From such a wide distribution it would seem that

Mitopus morio must be very flexible in its ability to adapt to its environment.

Its life history was worked out by Todd from specimens found in Wytham Woods, Oxford. (Todd. 1949) She found immature specimens from early April until July and mature specimens from July until October when *Mitopus* disappeared. She concluded that they over-wintered as eggs. This was substantiated by Phillipson (Phillipson. 1959) who found that around Durham *Mitopus* hatched in late March, matured July, laid eggs during August and September and died around October. These times varied with the weather conditions. From hatching to maturity there are seven instars which can be identified (see Chapter IVa).

The situation, of *Mitopus* being common both around Moor House (1700 - 2700 ft) and Durham (150 - 350 ft) was thought ideal for the study of the life history and how it is adapted to different climatic conditions.

Moor House has a severe climate (see Chapter IIc) and Durham one that is fairly mild for the N.E. of England. The season varies greatly between them, being April to October in Durham and only mid-May to the beginning of September on Moor House, a difference of nearly three months.

Clearly, a species which at low altitude in a mild climate takes from the end of March until mid-August to complete its life history (Phillipson. 1959) must be adapted to fit in with the shorter season and severe climate found at higher altitudes. Otherwise it would not complete its life history and the species would become extinct.

The cold temperatures found at high altitudes can affect animals in different ways; by slowing down the rate of development so that the life history is not completed or by affecting the distribution or life cycle of the food source.

To overcome these problems one of several adaptations must occur. The animal can prolong one stage of its life history so that it carries over more than one season. The Northern Eggar Moth Lasiocampa callunae (Palmer) spends two years as a larva whereas the original lowland race Lasiocampa quercus (L) spends only one in that stage.

It may however adapt by increasing its rate of development for a given temperature and therefore either take the same time in completing its life history or even shorten the time to fit in with the season.

In this study two size groups, clearly distinguishable by eye, were found on Moor House and had to be examined taxonomically and by statistical methods to see if they were part of the same or different populations and if either type was closely related to those found in Durham.

Most attention was paid to a comparison between the life histories of Mitopus in Durham and on five sites at different altitudes on Moor House. This included a determination of the instars, the rates of development at each site, respirometry and cultures at different temperatures.

II

MATERIALS AND METHODS

II (a)

MITOPUS MORIO

II (a) MITOPUS MORIO

M. morio is the commonest species of British harvestman and several people have studied it. Todd (1949) included it in her study of the harvestmen of Wytham Wood, Phillipson (1959, 1960a, 1960b, 1962) has used it for ecological, biological and energy transfer studies and Heighton (1964) also studied it amongst other harvestmen. However, all these studies were on the lowland form of Mitopus.

Several others have written on British harvestmen giving a general description of the features, ecology and distribution of Mitopus (Bristowe 1949; Hull 1926, 1930; Pearson and White 1964; William 1962; Sankey 1949, 1956; Savory 1938, 1962.)

Keys to the Opiliones have been published by Todd 1948, Savory 1943 and Hull 1930, but none of these describe Mitopus in detail.

The most comprehensive and by far the most accurate description is that of Pickard - Cambridge (1890) and the details of his description of Oligolophus morio, O. alpinus, and O. cinerascens now Mitopus morio, M. morio alpinus and M. morio cinerascens are given below.

Mitopus morio Fabricius 1779

This species is whitish yellow with a brown or black, sharply angulated dorsal mark shaped like an hour glass. This mark is often divided longitudinally by a pale stripe and bordered by a narrow white margin. Its denticulae are small which gives it a smooth appearance. The trident is also small with three main spines, the outer ones of which may be flanked by smaller more irregular ones. The ocularium is small and backward sloping with two rows of five to seven small denticulae. The legs are long, two being the longest then four, one and three. They are quite strong and often of a duller colour than the body with stripes or patches of brown and armed with spines. The pedipalp has a small hairy apophysis on the femoral joint. The insides of the pedipalps are also covered with hairs.

The sexes are distinguishable, the male being smaller, darker and more square with longer legs and stronger, whiter denticulae and heavier armature.

Pickard-Cambridge mentions samples from Scotland which were larger and more richly coloured than any he had found in S. England:

> "the abdominal band being deep yellow brown, pale along the middle broadly margined in black and surrounded with a distinct whitish yellow border; the denticulae were also stronger"

This is a good description of the larger form found on Moor House.

Mitopus morio alpinus Herbst 1799

> "This species is so nearly allied to the foregoing *M. morio* that it seems questionable to me whether it is really distinct or not."

It was first described in detail by Simon who distinguished the males from *M. morio* by the metatarsi of the third legs being curved, and thickened in the centre, and the first pair of legs having spines on the underside of the tibiae.

Pickard - Cambridge admits he could not find the first characteristic on any specimens, even those identified by Simon, and some definite lowland *M. morio* had spines on the lower surface of the tibiae although few in number. The females have never been separated.

Pickard - Cambridge concludes that

> "*O. morio* and *O. alpinus* with another quite as nearly allied, continental "species", *O. palliatus Latr*. embrace a widely dispersed, numerous, and exceedingly variable form, of which those inhabiting the lower and less elevated regions are *O. morio*, while those in the more mountainous or Alpine districts are *O. alpinus* and *palliatus*, the two latter presenting an extreme development of colours, markings and spiny armature, all of which are ... less marked and weaker in the plains ... "

Mitopus morio cinerascems Koch 1839

This is the smallest form but it is still very close to M. morio. It is greyish yellow with the colour of the band varying from very pale to almost black, divided by a pale or reddish stripe, and bordered in white. The denticulae are smaller and fewer in number than in the other forms and the legs are shorter, stronger and devoid of spines or denticulae. They, like M. morio alpinus belong to the northern and alpine districts but are easier to distinguish from M. morio.

Discussion

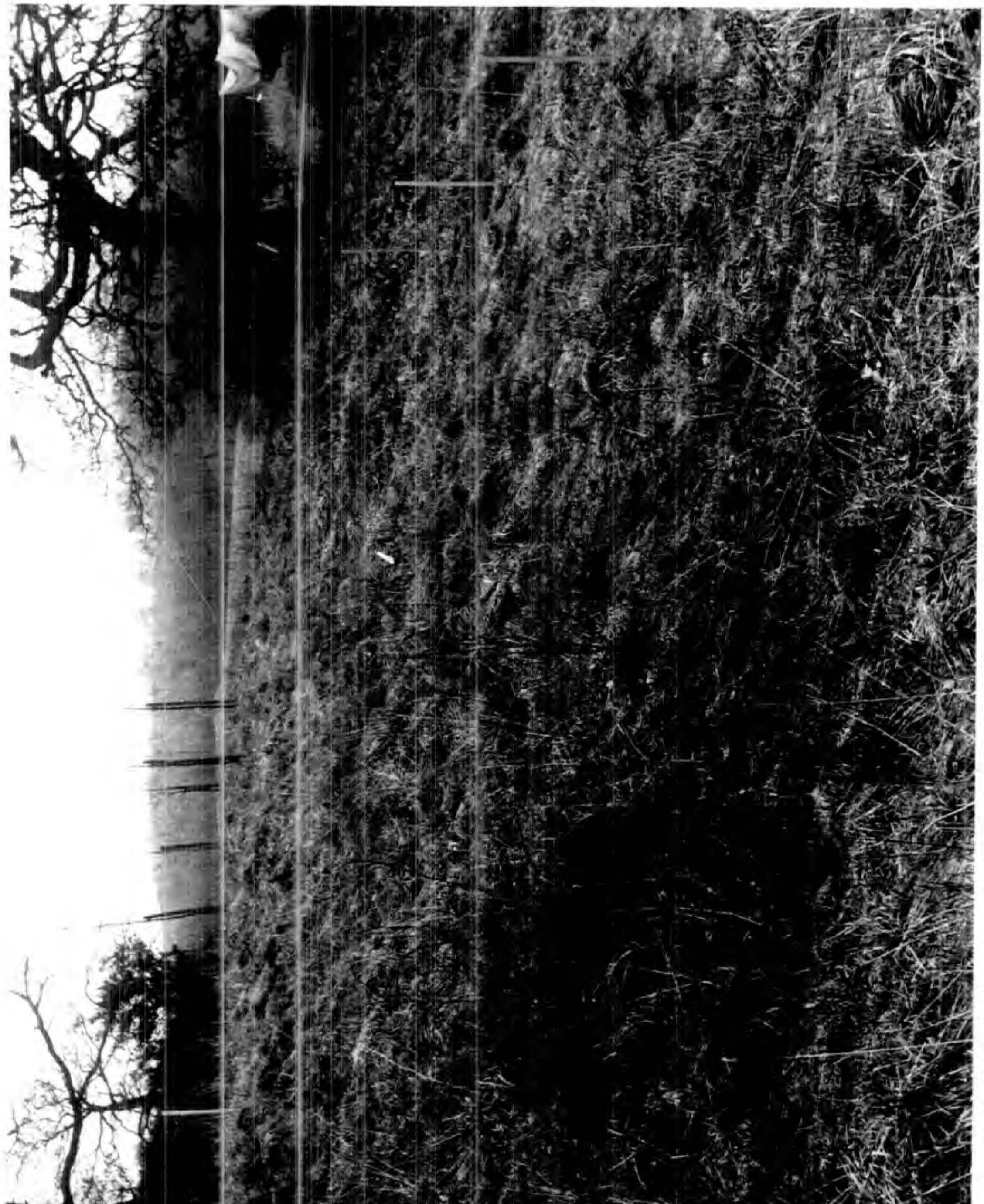
As these descriptions were of adults only and neither were available throughout most of the study, the three forms which were clearly distinguishable by eye in their immature stages had to be separated by statistical methods (see Chapter III). It is now concluded that all three forms were found, the Durham one being M. morio, the large Moor House form M. morio alpinus and the small form M. morio cinerascems.

II (b)

SITES AND COLLECTION METHODS

Plate I

Durham University Field Station Site



II (b) SITES AND COLLECTION METHODS

(a) General Characteristics

	DURHAM	BOG END	DUN FELL			
Altitude	250′	1800′	1700′	1900′	2500′	2700′
Aspect	WSW	N	NNW	W	NE	S
Slope	fair	gentle	flat	flat	flat	gentle
Bedrock	Coal measures	Yoredale series (Carbonif.)				
Drift		glacial				
Soil	Brown earth	Peat	peaty podsol	peaty podsol	peaty gley and podsol	solifluxion creep complex
Acidity	acid					
Dominant	Dactylis	Calluna	Juncus squarrosus			

(b) Details

(i) Durham University Field Station Grid. Ref. NZ 274406

The vegetation is one resulting from ungrazed pasture, the last sheep having been removed four years ago.

It consists of the following plants in order of abundance:-

Dactylis glomerata L.	Cocksfoot
Lolium perenne L.	Rye
Rubus sp. L.	
Rumex acetosa L.	Common sorrel

Crataegus monogyna L.	Hawthorn
Phleum pratense L.	Timothy
Geranium pratense L.	Meadow Cranesbill
Plantago lanceolata L.	Ribwort plantain
Urtica dioica L.	Stinging nettle
Achillea millefolium L.	Yarrow
Potentilla erecta L.	Common Tormentil
Aethusa cynapium L.	Fool's parsley
Festuca ovina L.	Sheep's Fescue
Holcus lanatus L.	Yorkshire Fog

This gives it an uneven, tussocky herb layer of Cocksfoot, Timothy and Rye remaining from the pasture, interspersed with herbs that have entered since it has been left ungrazed. There are a few shrubs but most of these are regularly cut down.

Fifty pitfall traps were put down in early March. They were placed in rows of ten with one metre between each jar and two and a half metres between rows.

Standard one-pound jam jars were used, with a little dilute detergent in the bottom. In July when the weather got warmer a little formalin was added to the detergent so that the captured animals did not rot. They were collected weekly. By that time however most samples were collected by hand from the grass and put into alcohol.

(ii) Bog End Moor House Nature Reserve Grid. Ref. NY 764329

The vegetation is one typical of Blanket bog, consisting of:-

Calluna vulgaris L.
Eriophorum vaginatum L.
Eriophorum angustifolium (Honck)
Juncus squarrosus L.
Sphagnum sp.
Polytrichum commune (Hedw.)
Rhytidiadelphus loreus (Hedw.)
Calypogeia trichomonas L.

Forty pitfalls were placed in two rows at the same intervals as on the field station. The process was also the same except that later in the season collections were made fortnightly because of transport difficulties.

(iii) Dun Fell 1700' Grid. Ref. NY 698296

The Dun Fell sites were originally chosen for another study of *Tipula Molophilus ater*. They are all situated on the western scarp of the Pennines except for 2500 ft. Moor House is on the eastern dip slope. They have very similar vegetation, dominated by *Juncus squarrosus*.

1700ft is a very damp site with pools of water all round. The vegetation is therefore slightly different from the other sites and consists of:-

Sphagnum cuspidatum (Ehrh.)
Sphagnum rubellum (Ehrh.)
Juncus squarrosus

Deschampsia flexuosa L.
Festuca ovina L.
Polytrichum commune
Galium saxatile L.
Potentilla erecta L.

Ten pitfall traps in two rows were used on each of the Dun Fell sites and collections were the same as at Bog End, i.e. once a week and then fortnightly.

(iv) Dun Fell 1900' Grid Ref. NY 705300

This site is a patch of *Juncus squarrosus* grassland in a general area of Blanket Bog. It is drier than the 1700 ft. site and therefore has no *Sphagnum*.

Juncus squarrosus
Deschampsia flexuosa
Festuca ovina
Polytrichum commune
Galium saxatile
Vaccinium myrtillus L.
Campylopus flexuosus (Hedw.)
Dicranium scoparium (Hedw.)

(v) Dun Fell 2500' Grid Ref. NY 724306

This site is just above an area of rapidly eroding blanket peat below the summit of Knock Fell.

Juncus squarrosus
Deschampsia flexuosa
Polytrichum commune
Sphagnum cuspidatum

Eriophorum vaginatum

Potentilla erecta

(vi) Dun Fell 2700' Grid Ref. NY 711319

Almost on the summit of Dun Fell, 2780', this site is surrounded by areas of bare rock. It has however a vegetation very similar to the other sites.

Juncus squarrosus

Polytrichum commune

Deschampsia flexuosa

Galium saxatile

Rhytidiadelphus loreus

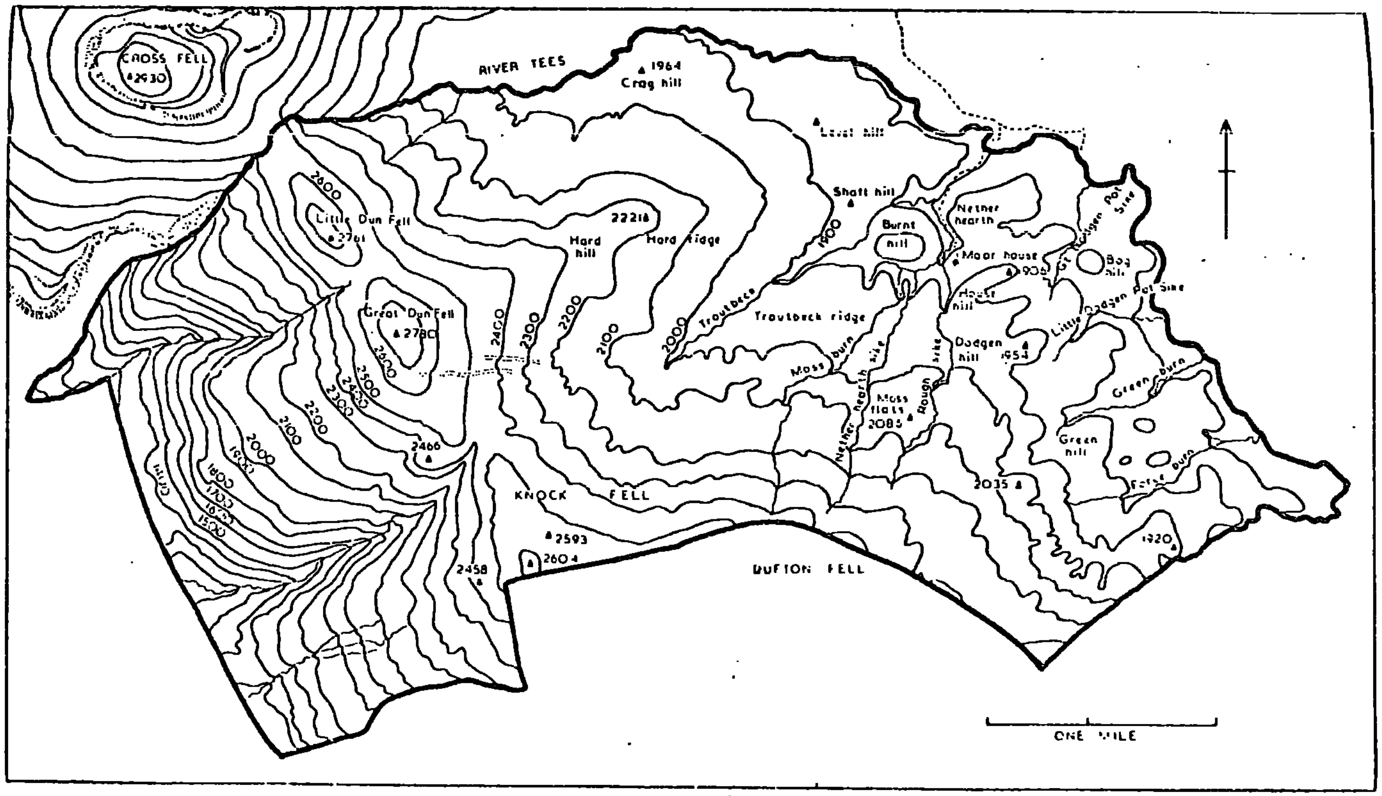


Fig. 1. Map of the Moor House National Nature Reserve showing the major topographical features. (Heights in feet: 1 ft = 0·305 m; 1 mile = 1·6 km approx.) AFTER CRAGG (1961)

II (c)

CLIMATE

II (c) CLIMATE

Moor House has a characteristically cold wet climate comparable to the sub-arctic one of the S. coast of Iceland (Manley 1936, 1942). The rainfall and humidity are high and the evaporation and temperatures low. Pearsall (1950) described it as typical of the British montane zone. Meteorological data have been collected there for a ten year period from 1935 to 1945 (Manley 1936, 1942) and continuously since 1952 when the weather station was established at 1840 ft. Certain records are also kept for Great Dun Fell 2780 ft.

Durham has had a weather station for many years and unlike Moor House is characterised by a low rainfall and warm temperatures.

Biologically the importance of this difference is that the growing period is much shorter on Moor House. A mean daily temperature of 5.6°C is the critical temperature at which plants grow in western Europe (Manley 1952). This value ensures that the night minimum is above 0°C. On the graph Fig. 1 this shows that the growing period was mid February to the end of October in Durham, early May to the beginning of October at Moor House and only mid May to mid September on the top of Dun Fell. This is a big difference as is that between the total daily temperature sums above 0°C.

Table 1. The total temperature sums of the different areas.

	Durham	Moor House	Dun Fell
Total temp. sums °C.	3164	1841	1379

Differences between the total temperature sums:

(i) Durham and Moor House 1323°C

(ii) Durham and Dun Fell 1785°C

(iii) Dun Fell and Moor House 461°C

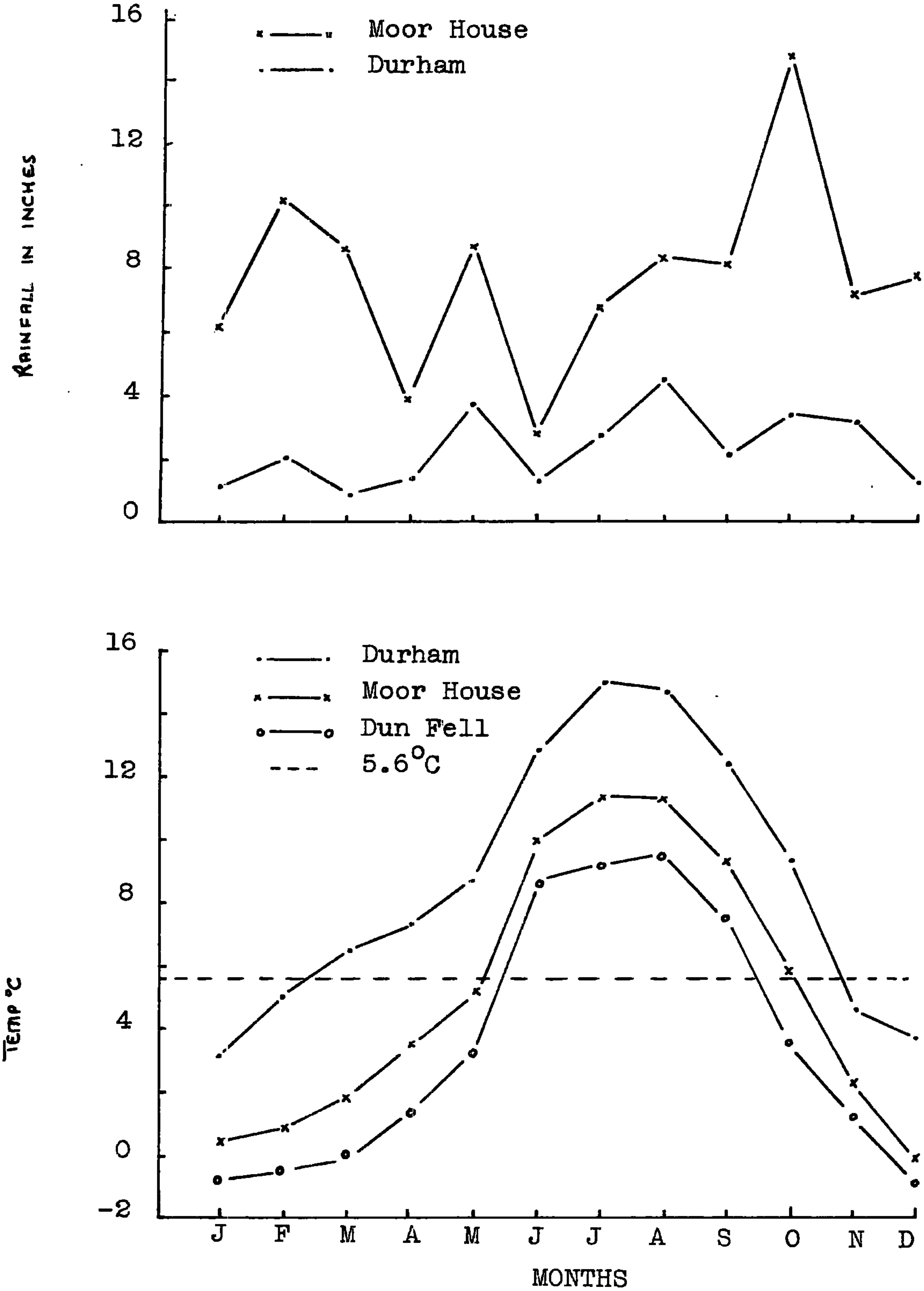
Table 2. Details of Weather Stations

	Durham	Moor House	Dun Fell
latitude	54°46'N	54°41'N	54°35'N
longitude	01°35'W	02°23'W	02°28'W
Grid ref.	NZ 267415	NY 757328	NY 710322
altitude	336 ft.	1840 ft.	2700 ft.

Table 3. Details of Climate

	Durham	Moor House	Dun Fell
Average Temp. °C	8.1	5.0	3.5
Rainfall (inches)	25.6	>70	-
Snow days (lying)	9	70	105
Gale days	-	49	127
Av. windspeed (knots)	7.46	15.6	19.9
Sunshine (total hrs.)	1371	1050	707

Fig. 1 The Comparison of (a) Rainfall and (b) Temperatures at Durham and Moor House (1967 latest available from Moor House).



III

THE SEPARATION OF THE DIFFERENT FORMS OF *MITOPUS*

III THE SEPARATION OF THE DIFFERENT FORMS OF MITOPUS

Introduction

While sorting out the collections from Moor House it was noted that there seemed to be a large and a small form and that both were different from the Durham form.

From the literature no reference to these could be found. All life history and biological studies have been done on lowland forms (Todd 1949; Phillipson 1959, 1960a, 1960b, 1962; Heighton 1964) and although some descriptions of British harvestmen (Hull 1926, 1930; Savory 1948) mentioned three varieties of Mitopus, no full descriptions of them or mention of marked differences could be found.

The three forms could be just different size groups of the same population with perhaps an extra instar in the large form, or they could be the three different varieties Mitopus morio morio, M. morio alpinus and M. morio cinerascens.

However, after the following separation had been undertaken and completed, full descriptions of the three varieties were found (Pickard - Cambridge 1890) (see Chapter II(a)) and the most likely explanation seems to be that they are the different varieties.

Materials and Methods

For a full description of the three varieties see Chapter II(a). The two forms of Mitopus found on Moor

House and separable by eye were different in several ways. (See Plate 2)

The large form was larger in every way, (see Table 4.), thicker legged and heavier. They were pale creamy buff colour with dark chocolate brown markings. The characteristic hour glass was much more indented and surrounded by a clear edging.

The smaller form had short legs and was a yellowish buff colour. The hour glass was sometimes very dark but often chestnut with a white border and a reddish or yellow central stripe.

The Durham form was not so clearly marked and usually more generally brown. It was much larger than the small form but not so large as the large Moor House form.

All three types were compared in many ways by use of specific characters, by dry weights and by measurements.

The dry weights were used as wet weights vary with the state of hydration of the animal. Ten of each sex from each form were dried at 60°C in a vacuum oven for several days until a constant weight was reached. The mean weight was calculated.

Measurements were taken first of body length, although this varies with wet weight, femur lengths, femur widths, leg lengths, and the number of tarsal joints.

The ratio of femur length to width was determined and as they seemed to be so different for the different Moor House forms this was determined for all the instars of all three forms and plotted against the femur length.

The specific characteristics studied were the structure of the trident, femorae, tibiae, chelicerae, metatarsi, penis or oviduct.

Results

The only differences that could be seen in the structure of the forms was that the trident was larger in the large form, the chelicerae, tibiae and femorae were more heavily armoured and the penis and oviduct were more heavily pigmented.

The small form had much less armature on the legs.

The dry weights were considerably different.

Table 4. Mean Measurements of Different Forms (mm)

	DURHAM		LARGE M.H.		SMALL M.H.	
	Mean	SE	Mean	SE	Mean	SE
Body length	5.34	0.0803	6.53	0.1840	4.13	0.1020
Femur length						
1	2.73	0.0591	3.01	0.0457	1.71	0.0253
2	4.54	0.1122	4.79	0.0922	2.65	0.0278
3	2.83	0.0541	3.13	0.0548	1.75	0.0357
4	4.63	0.09700	4.76	0.0788	2.74	0.0353
Femur width						
1	0.393	0.0049	0.458	0.0076	0.365	0.0047
2	0.298	0.0019	0.358	0.0061	0.294	0.0029
3	0.363	0.0065	0.423	0.0051	0.347	0.0045
4	0.314	0.0057	0.374	0.0067	0.306	0.0038
Leg length						
1	15.29	0.2715	16.53	0.0753	9.82	0.1377
2	25.14	0.4657	26.08	0.2690	15.10	0.1783
3	17.06	0.3004	18.32	0.3319	10.53	0.1674
4	24.83	0.4081	25.52	0.1524	15.39	0.1825
Tarsal joints						
1	32.3	0.4910	38.0	0.5292	29.4	0.4290
2	48.4	0.6812	55.6	0.5330	44.0	0.6929
3	33.0	0.5292	40.0	0.4000	30.6	0.5693
4	38.2	0.6753	45.9	0.4111	35.0	0.7747

Table 5. The Dry Weights (mean of ten) of the Different Forms of Mitopus

	DURHAM	LARGE	SMALL
Dry wt. ♀ mgs.	14.58	12.37	1.99
Dry wt. ♂ mgs.	4.14	5.60	1.25

The differences between the dry weights of females and males is due to the fact that the females were carrying eggs. However, the small form had hardly any eggs at that stage and therefore there is not such a marked difference.

Table 6. The Mean Ratios of Femur Length:Width for the Adults of the Large and Small Forms and those from Durham.

	LARGE		SMALL		DURHAM	
leg	RATIO	SE	RATIO	SE	RATIO	SE
1	6.5777	0.1392	4.6991	0.0651	6.9548	0.6910
2	13.4275	0.3850	9.0136	0.0407	15.2484	0.3805
3	7.4171	0.1407	5.0375	0.0812	7.8142	0.2067
4	12.7660	0.2709	8.8661	0.1148	14.7983	0.4515

Students t-tests were done between the means of the ratios for each leg.

Table 7. Results of Students t-test between Large and Small Forms, Ratio of Femur Length:Width

leg	t	^{o}f	p
1	12.2249	18	$\ll 0.001$
2	11.4011	18	$\ll 0.001$
3	14.6482	18	$\ll 0.001$
4	13.2550	18	$\ll 0.001$

Table 8. Results of Students t-test between Durham and Large Forms, Ratio of Femur Length to Width.

leg	t	^{o}f	p	
1	0.5349	18	> 0.1	
2	3.3639	18	< 0.01	
3	1.5881	18	> 0.1	
4	3.8598	18	< 0.01	

Table 9. Mean Femur Length and Mean Ratio of Femur Length:Width for 2nd - 7th Instars of all Three Forms.

Durham

Instar	Femur Length (mm)	SE	Ratio	SE
2	0.70	0.0187	6.0740	0.2986
3	1.1257	0.0204	7.7760	0.1925
4	1.540	0.0230	9.0214	0.2797
5	2.245	0.0512	9.8410	0.3580
6	3.220	0.0686	11.7234	0.5559
7	4.54	0.1122	15.2480	0.3805

Moor House

Large

Instar	Femur Length (mm)	SE	Ratio	SE
2	0.955	0.0179	6.9594	0.1553
3	1.315	0.0089	7.9885	0.1527
4	2.100	0.0437	10.1838	0.0578
5	2.529	0.0552	9.9082	0.1855
6	3.748	0.0684	11.6992	0.4902
7	4.790	0.0922	13.4275	0.3850

Small

Instar	Femur Length (mm)	SE	Ratio	SE
2	0.675	0.0650	6.4217	0.1689
3	1.0167	0.0148	7.1818	0.0857
4	1.3025	0.0487	7.6674	0.2335
5	1.6350	0.0581	7.4251	0.1036
6	1.9750	0.0245	7.5226	0.1677
7	2.6500	0.278	9.0136	0.0407

Fig. 2 The Femur Length to Width against Femur Length of the Durham Form.

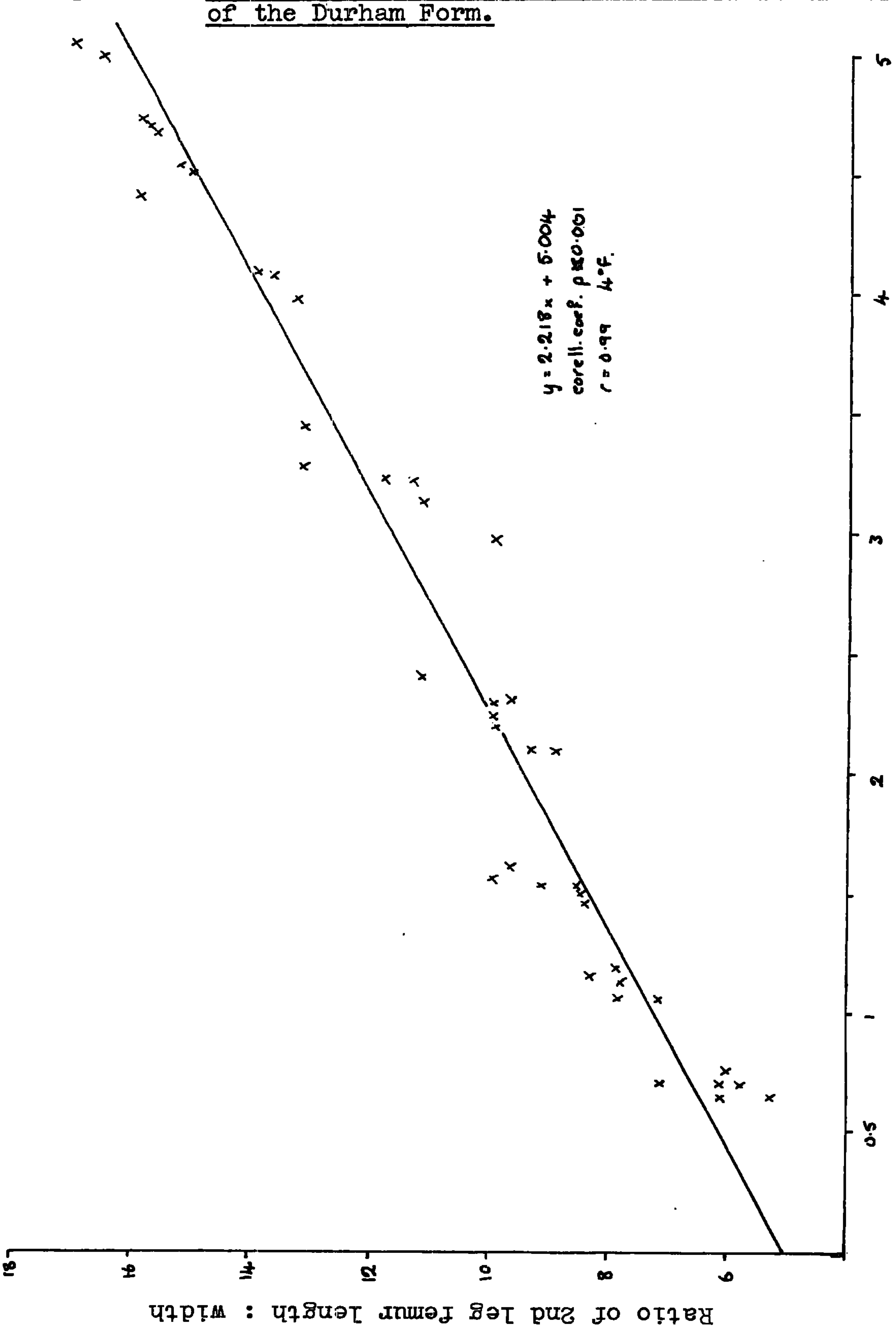


Fig. 3 <u>The Ratio of Femur Length to Width against Femur Length for the Large Moor House Form</u>

(- - - Small Form)

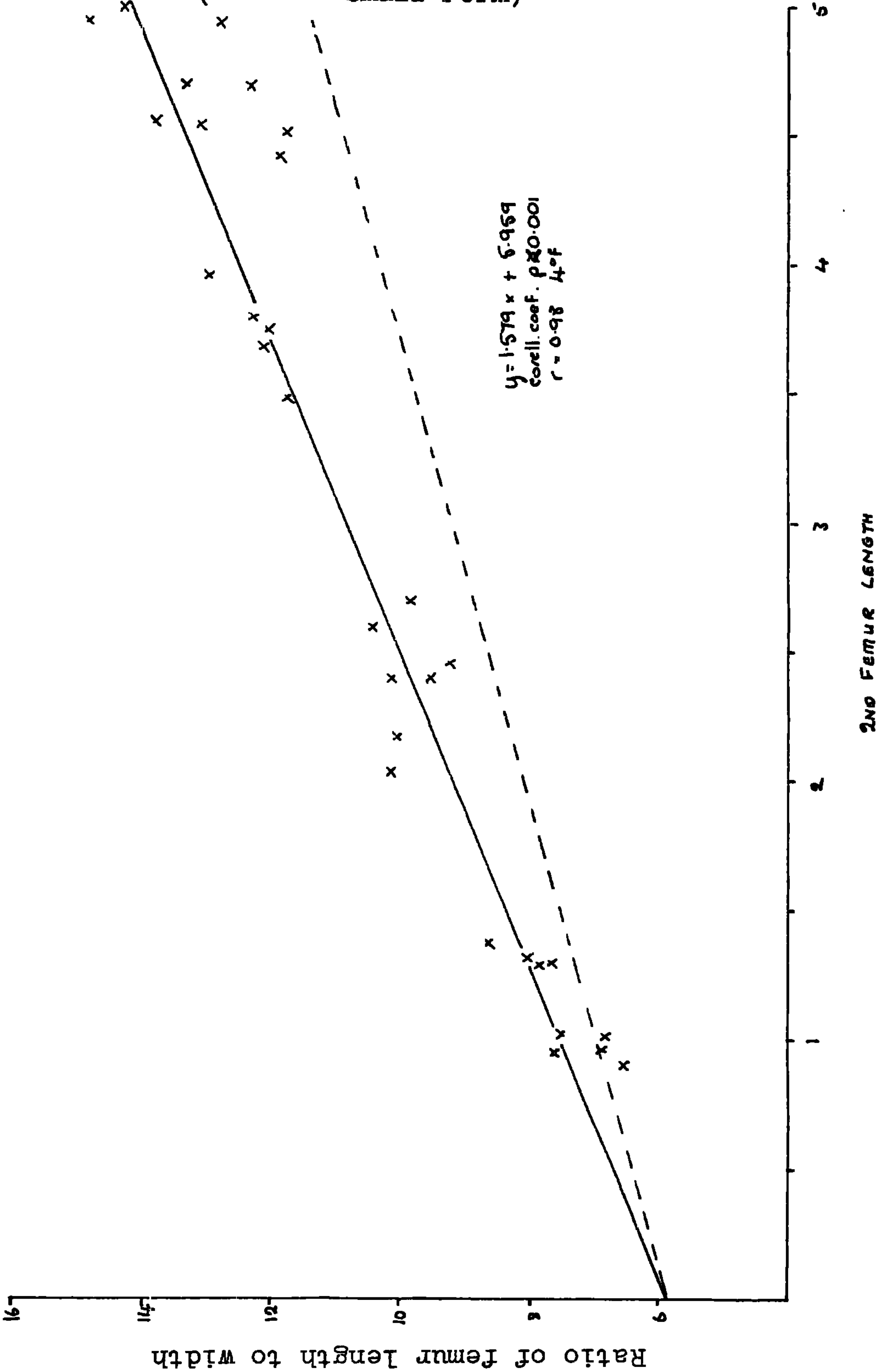


Fig. 4 The Ratio of Femur Length to Width against Femur Length for the Small Moor House Form

(- - - large form)

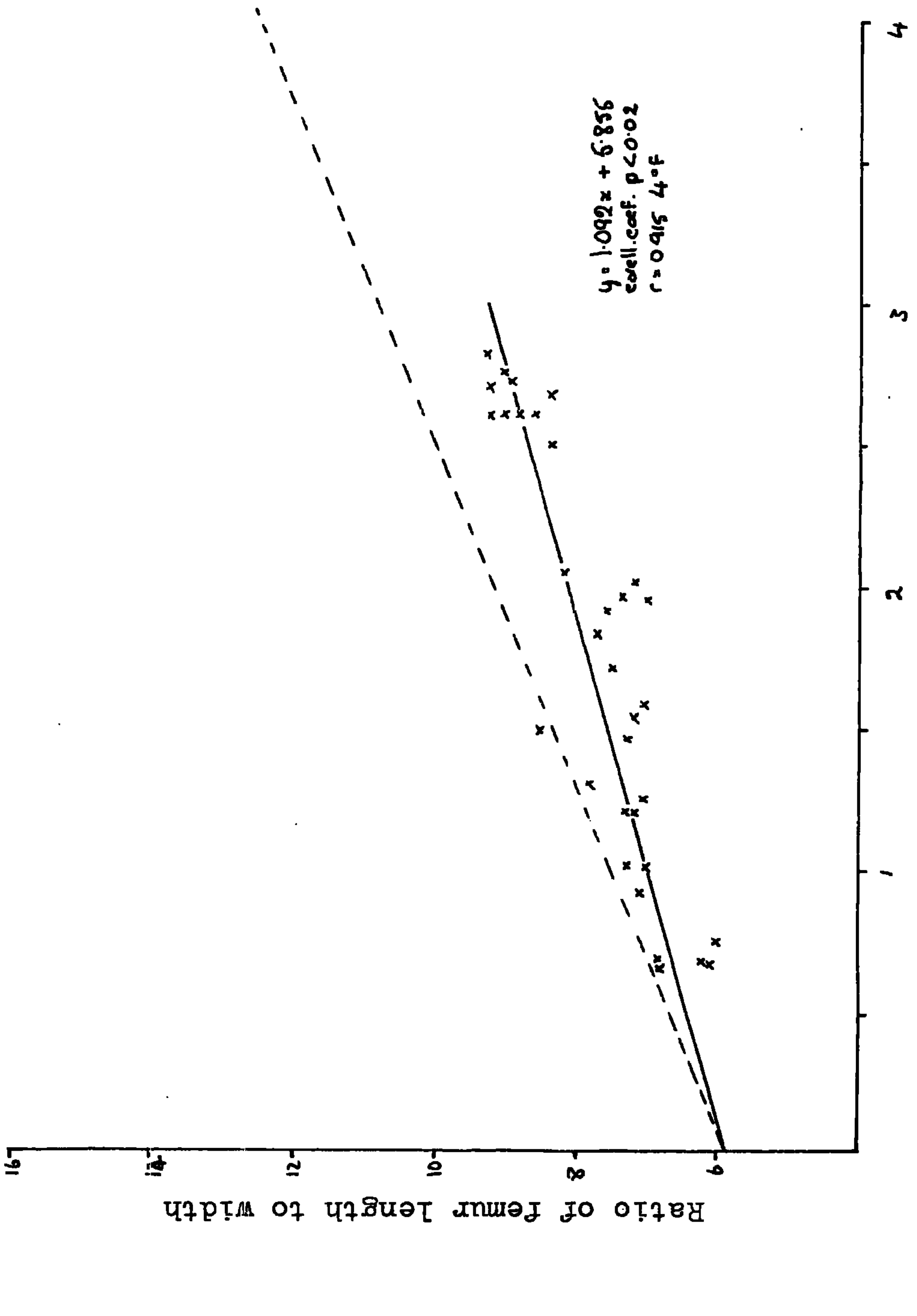


Plate II

Mitopus morio alpinus

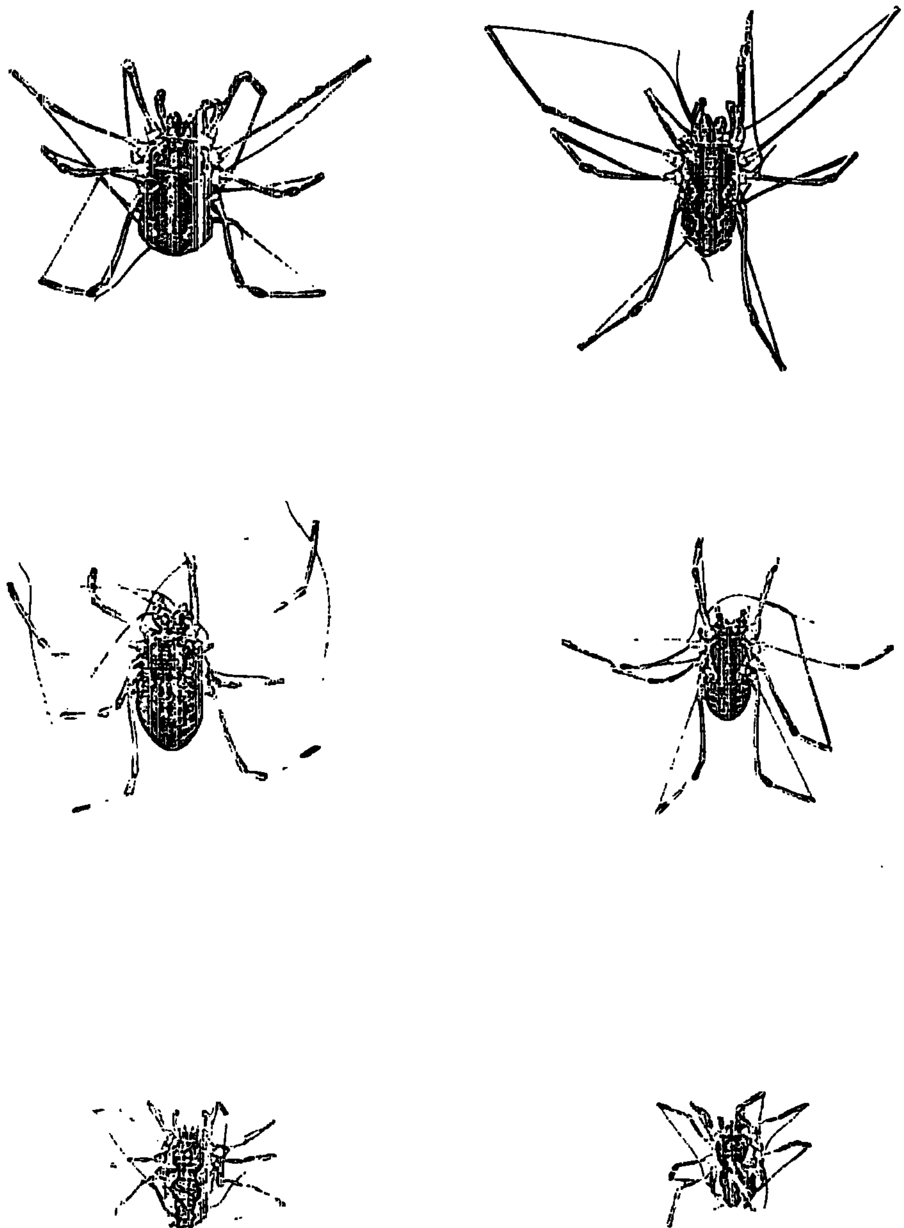
♀ ♂

Mitopus morio

♀ ♂

Mitopus morio cinerascens

♀ ♂



Discussion

The measurements and dry weights show clearly the differences in size of the three forms of Mitopus; but they do not prove in any way that the forms could be anything but size groups of the same population.

However, the information on ratios of femur length to width and the graphs of these ratios against femur length indicate that the ratios are different for a given femur length in the different forms, e.g. at femur length around 2.6 the large variety have a ratio of 10 and the small variety one of only 9. If the three forms were just size groups of one population the ratio would be the same in all three cases for a given femur length.

These results fit in well with the descriptions of the three varieties of Mitopus, morio, alpinus and cinerascens given by Pickard - Cambridge (1890), (see Chapter II(a)). In fact at that time they were classified as different species of the genus Oligolophus (Banks). They were taken from that genus when Roewer divided it into four genera and he put Oligolophus morio, O. alpinus and O. cinerascens into the species Mitopus morio and classed them as varieties.

IV

SEASONAL DEVELOPMENT

IV (a)

DETERMINATION OF THE INSTARS

IV (a) DETERMINATION OF THE INSTARS

Before the rate of growth and thus the seasonal development for the different varieties of Mitopus could be worked out, the different stages in the life history had to be easily recognised. As was said in the general introduction, Mitopus has seven instars between hatching and adult. The first instar only lasts a few minutes and can be determined by the fact that the animal has a large egg tooth on the front of the cephalothorax. The moult occurs while the animal is still in the egg case and is never found in the field, (Heighton 1964). The other instars have to be determined by size differences. This method is described by Gabbutt (1959) for the Wood Cricket Nemobius sylvestris (Bosc) in which case the head width was used. Heighton (1964) used the same method to separate Mitopus instars but measured the 2nd leg femur length. His method was used in this study.

Methods

When a collection was made from each site all or thirty specimens of Mitopus, whichever was the least, were sorted out from it and used for the measurements.

The second leg femur length was measured under the microscope and the result recorded in millimetres.

When collections were completed the frequencies of the lengths were plotted as histograms (see Figs. 5 and 6) and the resulting peaks were used to determine the instars, knowing which ones were adults and that the earliest instar found should be the second. From this the mean femur length for each instar could be determined. The growth increment between each moult was found for each variety of <u>Mitopus</u> and for <u>M. morio cinerascens</u> at each site on Moor House by dividing the mean femur length for each instar by that of the previous instar.

<u>Results</u>

The results are summarised in the following tables and in Figs. 5, 6 and 7.

Table 10. <u>The Growth Increments between each Moult</u>

		Variety and Site						
	<u>morio</u>	<u>alpinus</u>	<u>cinerascens</u>					
Instar	Durham	Moor House	Bog End	1700'	1900'	2500'	2700'
2							
	1.52	1.43	1.30	1.38	1.49	1.23	1.40
3							
	1.46	1.43	1.35	1.35	1.21	1.37	1.29
4							
	1.41	1.32	1.32	1.30	1.40	1.38	1.21
5							
	1.37	1.48	1.28	1.35	1.32	1.30	1.32
6							
	1.50	1.35	1.28	1.32	1.35	1.27	1.24
7							

Table 11. The Mean Growth Increments calculated from Values in Table 10.

Variety	Site	Mean Growth I.	St. Deviation	N.
morio	Durham	1.45	0.055	5
alpinus	Moor House	1.40	0.058	5
cinerascens	Bog End	1.31	0.030	5
"	1700'	1.34	0.027	5
"	1900'	1.35	0.093	5
"	2500'	1.31	0.056	5
"	2700'	1.29	0.067	5

Table 12. The Mean Femur Lengths for each Instar

(a)

	Variety and Site					
	cinerascens					
	1700'			1900'		
Instar	Mean femur length (mms)	SD	N	Mean femur length (mms)	SD	N
2	0.73	0.03	16	0.67	0.16	20
3	1.00	0.04	12	0.99	0.04	7
4	1.35	0.04	7	1.21	0.04	2
5	1.76	0.48	18	1.69	0.62	9
6	2.38	0.15	33	2.28	0.35	50
7	3.30	0.32	10	3.23	0.27	10

(b)

	Variety and Site					
	<u>c i n e r a s c e n s</u>					
	2 5 0 0'			2 7 0 0'		
Instar	Mean femur length (mms)	SD	N	Mean femur length (mms)	SD	N
2	0.72	0.05	6	0.72	0.05	8
3	0.88	0.04	5	1.02	0.08	5
4	1.21	0.05	5	1.32	0.01	3
5	1.66	0.09	29	1.59	0.31	31
6	2.16	0.11	27	2.09	0.14	17
7	3.24	0.22	10	3.43	0.08	10

(c)

	Variety and Site					
	<u>m o r r i n o</u>			<u>a l p i n u s</u>		
	D u r h a m			M o o r H o u s e		
Instar	Mean femur length (mms)	SD	N	Mean femur length (mms)	SD	N
2	0.71	0.04	27	0.95	0.05	9
3	1.09	0.06	19	1.35	0.03	7
4	1.59	0.05	23	1.94	0.10	3
5	2.25	0.01	33	2.56	0.17	14
6	3.09	0.13	68	3.80	0.56	33
7	4.62	0.36	46	5.14	0.58	48

(d)

	Variety and Site		
	<u>cinerascens</u>		
	Bog End		
Instar	Mean femur length (mms)	SD	N
2	0.69	0.04	19
3	0.90	0.06	3
4	1.22	0.05	23
5	1.62	0.63	35
6	2.06	0.16	33
7	2.64	0.10	22

Table 13. Results of Students t-test between Mean Growth Increments.

Between Varieties		t	^{o}f	p
Durham morio	Bog End cinerascens	5.2219	8	<0.001
"	1700' cinerascens	4.1031	8	<0.01
"	Moor House alpinus	1.4108	8	>0.1
Moor House alpinus	Bog End cinerascens	3.2706	8	<0.02
"	1700' cinerascens	2.1573	8	>0.1
Bog End cinerascens	1700' cinerascens	1.8789	8	>0.1
2700' cinerascens	"	1.5954	8	>0.1

Table 14. Limits of each Instar, 2nd Leg Femur Lengths as determined from the Instar determination and used in Separation.

	Variety and Site						
	Morio	Alpinus	C i n e r a s c e n s				
Instar	Durham	Moor House	Bog End	1700'	1900'	2500'	2700'
1							
	0.63	0.84	0.60	0.66	0.60	0.60	0.61
2							
	0.89	1.18	0.78	0.84	0.95	0.84	0.84
3							
	1.29	1.59	1.06	1.19	1.09	1.03	1.02
4							
	1.96	2.17	1.35	1.42	1.40	1.39	1.35
5							
	2.65	2.75	1.70	2.08	2.00	1.91	1.81
6							
	3.62	4.45	2.40	2.78	2.70	2.35	2.35
7							

Fig. 5 Frequency of Femur Lengths against Femur Length for *M. morio cinerascens* (▩= adults)

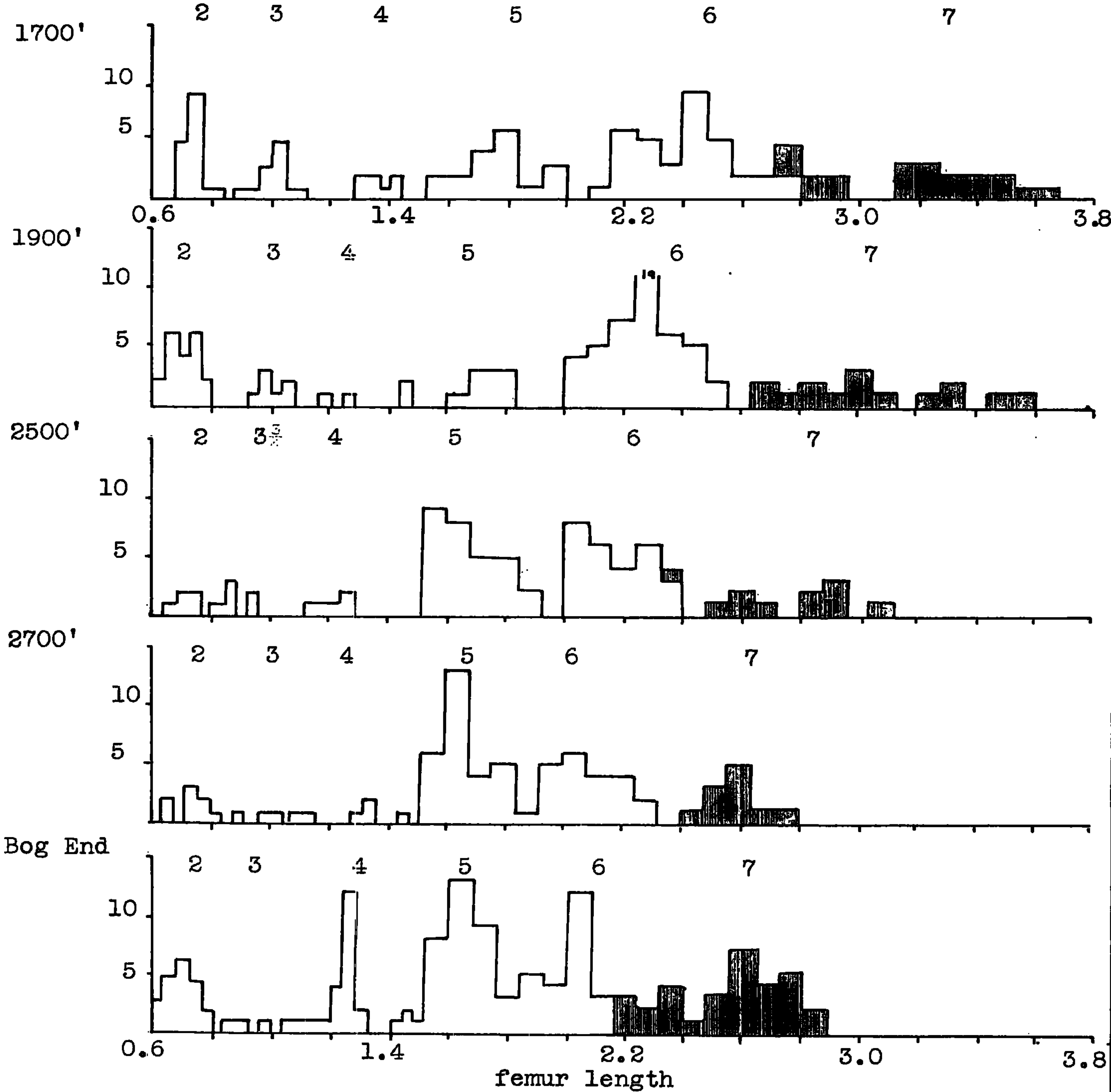


Fig. 6 Frequency of Femur Length to Log Femur Length for M. morio and M. morio alpinus (▦ = adult)

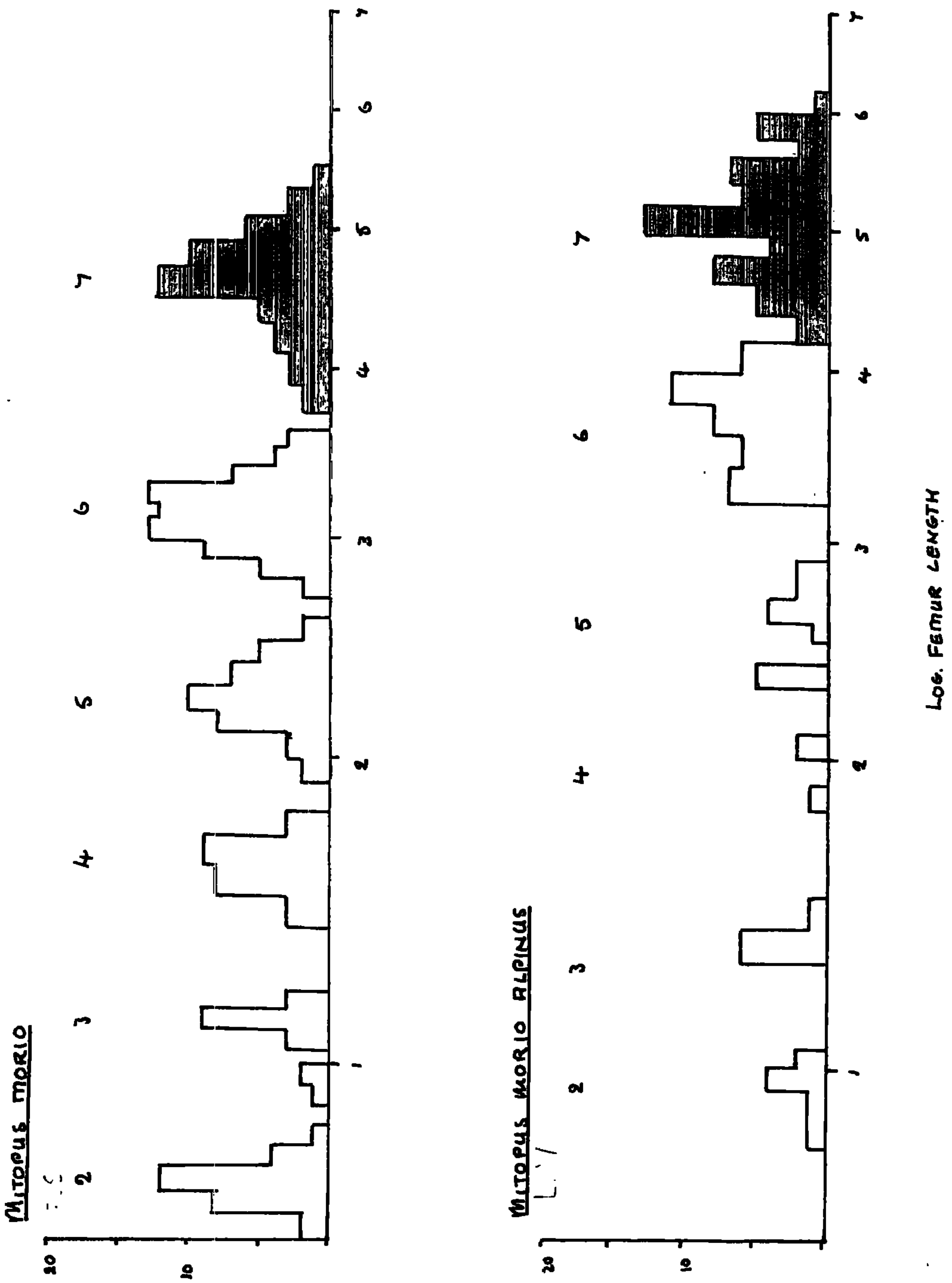
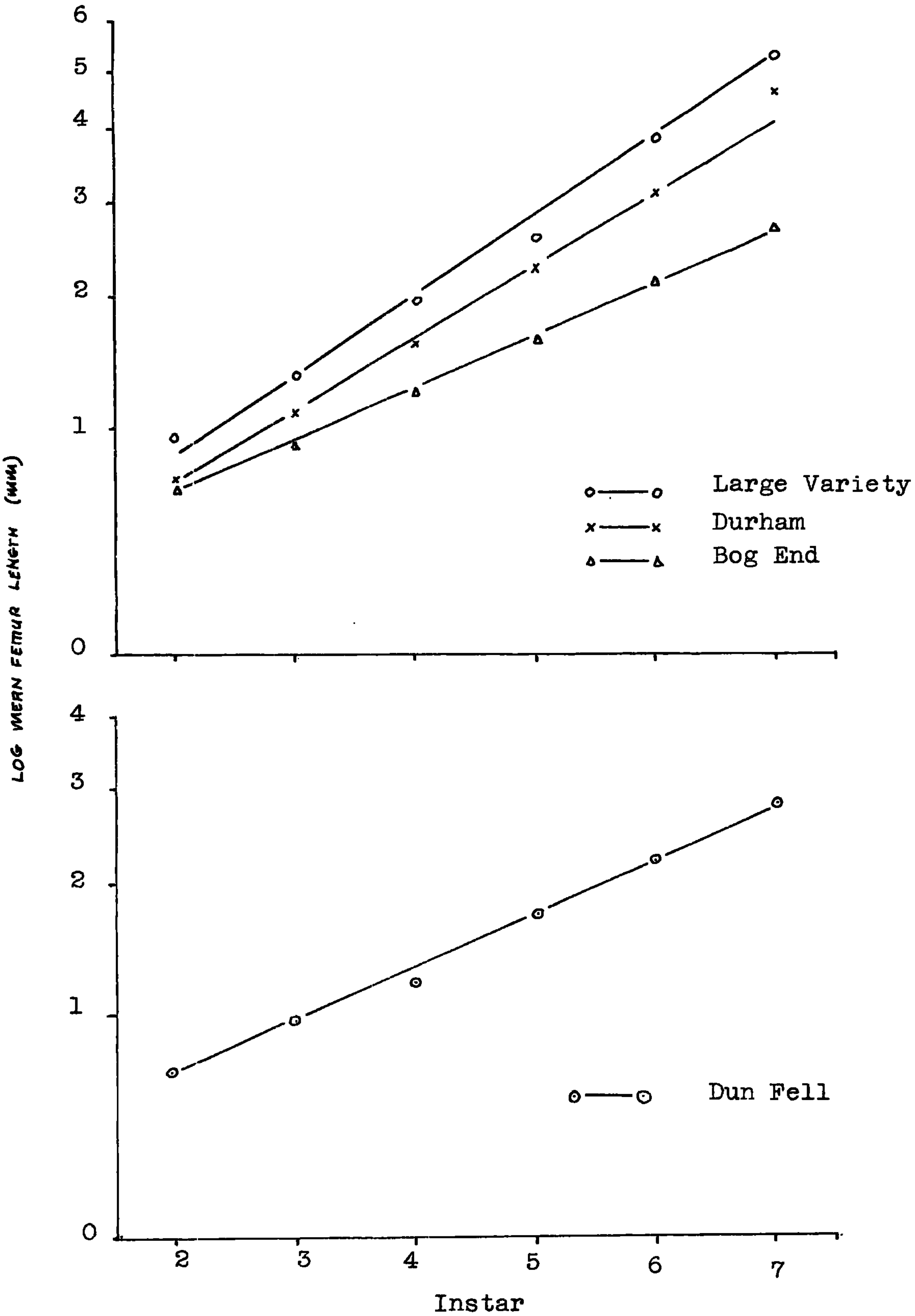


Fig. 7 <u>Log Mean Femur Length against Instar</u>



Discussion

The histograms (see Figs. 5 and 6) show non-overlapping peaks for *M. morio* in Durham. This makes the instars easy to separate, each instar being represented by a peak. However, the peaks do not completely separate on other sites but they can still be divided, if not quite so easily, into different instars.

The other variety most like *M. morio* is *M. morio alpinus* which has almost the same growth increment but the stages are bigger throughout.

M. morio cinerascens shows an interesting reduction in size on the altitude transect towards the summit of Great Dun Fell, 2700 ft. (highest site); but the Bog End samples are equivalent to the smallest Dun Fell specimens although they come from almost 1000 ft. lower, on the dip slope of the Pennines. This is probably because it is very wet at Bog End.

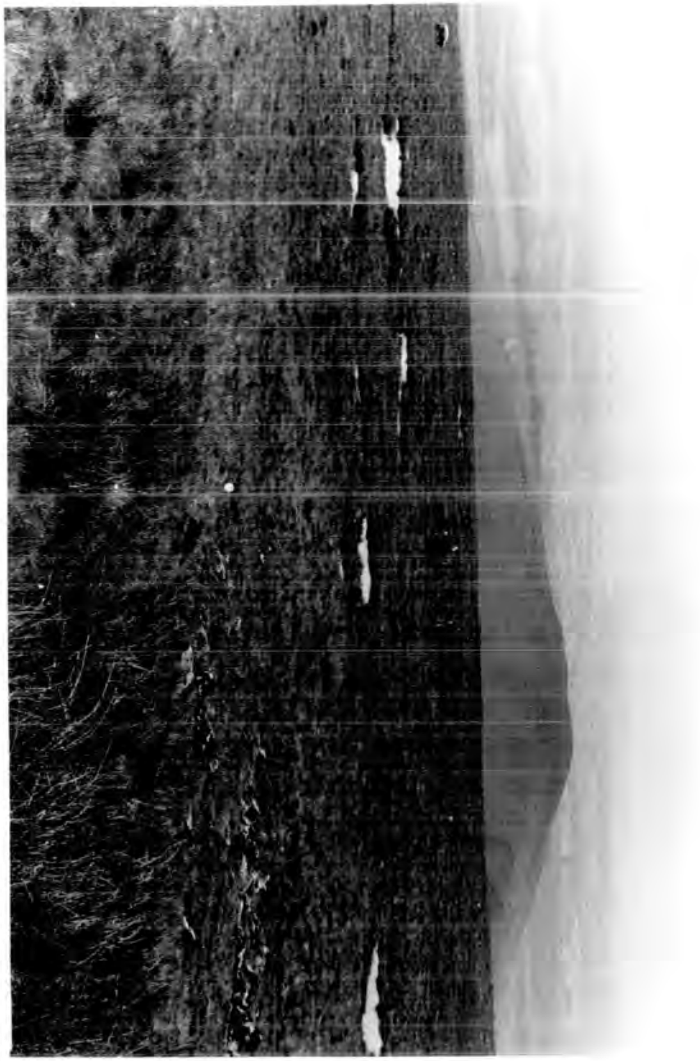
The graphs of log mean femur length to instar show a linear relationship. The growth must therefore be exponential. Those for Dun Fell and Bog End, all *M. morio cinerascens*, are so alike that they have the same regression line, but *M. morio* from Durham and *M. morio alpinus* are both different from it and each other. This means they are different sizes and have different growth increments.

The Students t-tests show that only M. morio cinerascens has a growth increment significantly different from the other varieties. It has not, however, got a growth increment significantly different at its smallest, 1.29 at 2700 ft. from the largest, 1.35 at 1900 ft.

Plate III

Juncus squarrosus and _Polytrichum_

Great Dun Fell 1700' Site



IV (b)

DEVELOPMENTAL HISTORY

FROM PITFALL DATA

IV (b) DEVELOPMENTAL HISTORY FROM PITFALL DATA

Introduction

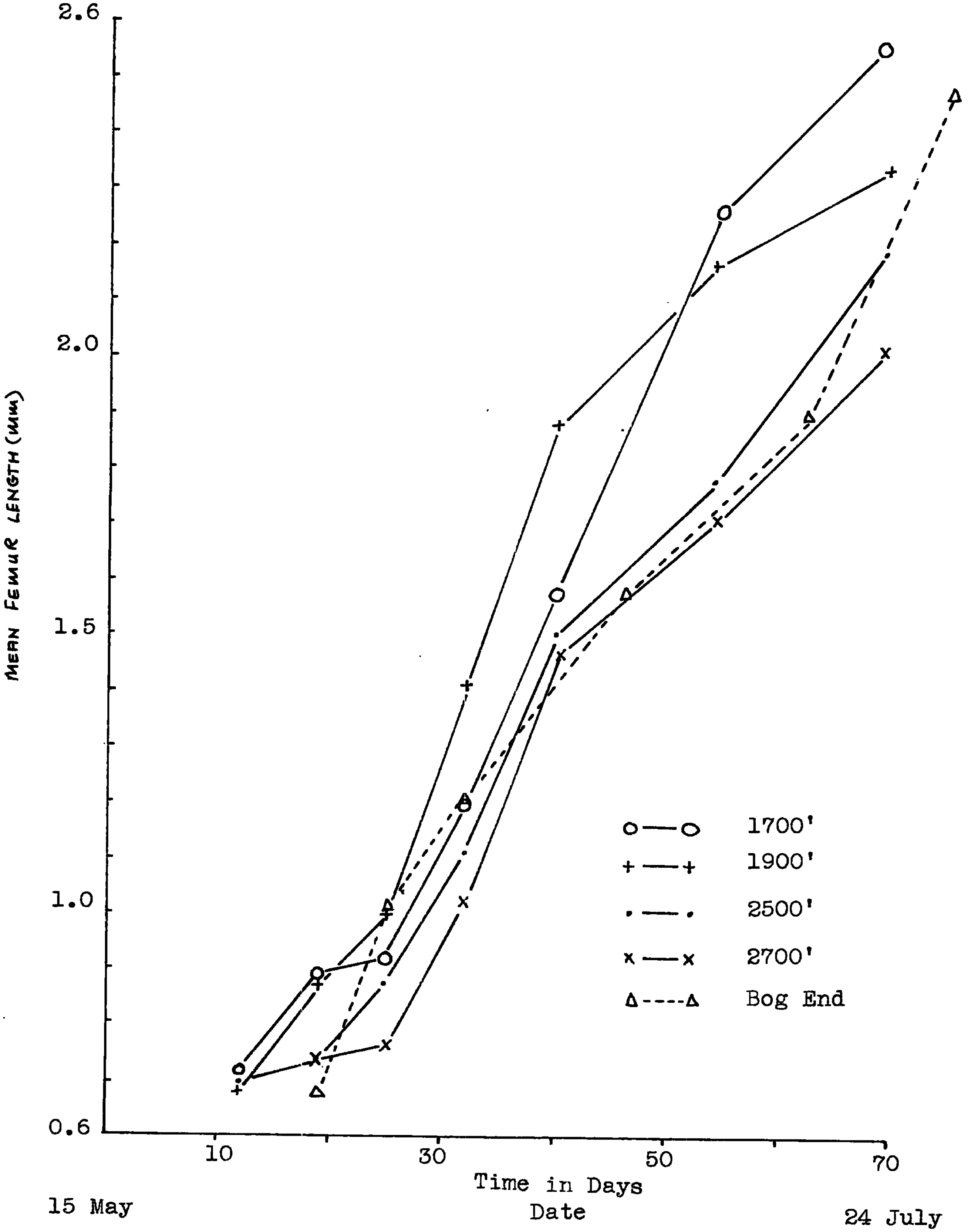
Todd (1949) and Phillipson (1959) both found that Mitopus morio hatched in late March or early April and matured in July.

Because of this collections were started at the beginning of March so that the early instars would not be missed. In fact the first specimens were found 1. May in Durham and not until 20. May at Moor House.

Methods

Collections were trapped in pitfalls or straight from the grass as described in Chapter II(b). They were made at weekly intervals in Durham and at weekly, then fortnightly intervals at Moor House. Samples were preserved in 70% alcohol and the second femur length of each specimen measured under the microscope and recorded in millimetres. The mean femur length and the mean instar (see Chapter IV(a) for instar separation) for each collection at each site was determined and plotted against the date (see Figs. 8, 9, 10, 11 and 12) to give an estimate of growth rate.

Fig. 8 Mean Femur Length against Date



Results

Table 15. The Mean Femur Lengths and Mean Instars for Durham Collections.

Date	Day	Mean Femur Length (mm)	SD	N	Mean Instar	SD	N
1 May	-	0.70	0.0274	4	2.0	-	4
8	-	0.73	0.0458	5	2.2	0.4000	5
15	0	0.73	0.0721	14	2.0714	0.2575	14
22	7	0.92	0.2198	11	2.5455	0.4979	11
29	14	1.11	0.2561	7	3.0000	0.5345	7
5 June	21	1.14	0.2047	6	3.1667	0.3727	6
13	29	1.53	0.1939	13	4.0000	0.5547	13
19	35	2.02	0.3522	27	4.8519	0.7047	27
26	42	2.46	0.1183	30	5.0333	1.1101	30
3 July	49	3.07	0.4680	30	5.8333	0.3727	30
10	56	3.34	0.0636	30	6.3333	0.1491	30
17	63	3.71	1.0521	30	6.5333	0.4989	30
24	70	4.51	0.9057	30	7.0000	-	30

Table 16. The Mean Femur Lengths and Mean Instars for Moor House Collections.

M. morio alpinus

Date	Day	Mean Femur Length (mm)	SD	N	Mean Instar	SD	N
20 May	5	0.95	0.0588	8	2.0	-	8
27	12	1.16	0.1650	2	2.5	0.5000	2
3 June	19	1.37	0.0343	5	3.0	-	5
9	25	1.73	0.2824	3	3.6667	0.4690	3
16	32	2.54	0.8937	11	4.9091	0.2864	11
24	40	3.14	0.5676	3	5.6667	0.4703	3
30	46	3.04	0.6067	5	5.4000	0.4899	5
8 July	54	3.65	0.3495	14	6.0000	-	14
16	62	4.22	0.6633	28	6.2857	0.4517	28
22	68	4.74	0.5650	21	6.9524	0.2124	21
29	75	5.39	0.3525	21	7.0000	-	21

M. morio cinerascens

Bog End

Date	Day	Mean Femur Length (mm)	SD	N	Mean Instar	SD	N
20 May	5	0.76	0.02	10	2.0000	-	10
27	12	0.69	0.0485	8	2.0000	-	8
3 June	19	0.68	0.0319	10	2.0000	-	10
9	25	1.02	0.0350	2	3.0000	-	2
16	32	1.21	0.1072	25	4.040	1.0778	25
30	46	1.59	0.4592	29	5.0690	0.4496	29
16 July	62	1.90	0.1888	28	6.0000	1.0351	28
29	75	2.48	0.2954	30	6.7667	0.4230	30

Table 17. The Mean Femur Lengths and Mean Instars for Dun Fell Collections.

1700'

Date	Day	Mean Femur Length (mm)	SD	N	Mean Instar	SD	N
20 May	5	0.73	0.0141	3	2.0	-	3
27	12	0.72	0.0400	9	2.0	-	9
3 June	19	0.89	0.1519	11	2.5455	0.4979	11
9	25	0.92	0.0300	2	3.0000	-	2
16	32	1.20	0.1840	5	3.6000	0.4899	5
24	40	1.58	0.2854	16	4.6250	0.6960	16
8 July	54	2.27	0.3168	29	5.7586	0.4279	29
22	68	2.56	0.6573	29	6.2759	0.5184	29

1900'

20 May	5	0.71	0.0346	8	2.0000	-	8
27	12	0.68	0.0494	10	2.0000	-	10
3 June	19	0.87	0.1465	4	2.5000	0.5000	4
9	25	1.00	0.0327	4	3.0000	-	4
16	32	1.42	0.2640	6	4.5000	0.7638	6
24	40	1.88	0.0987	5	5.2000	0.4000	5
8 July	54	2.17	0.2868	27	5.8148	0.4743	27
22	68	2.34	0.5307	28	6.0714	0.3712	28

2500'

Date	Day	Mean Femur Length (mm)	SD	N	Mean Instar	SD	N
27 May	12	0.69	0.0287	3	2.0000	-	3
3 June	19	0.74	-	1	2.0000	-	1
9	25	0.87	0.0499	3	3.0000	-	3
16	32	1.11	0.1337	9	3.6667	0.4714	9
24	40	1.53	0.3265	8	4.625	0.9922	8
8 July	54	1.79	0.2482	26	5.2308	0.4213	26
22	68	2.19	0.2438	25	6.000	0.4000	25
2700'							
3 June	19	0.74	0.0200	2	2.0000	-	2
9	25	0.77	0.0924	9	2.4444	0.4969	9
16	32	1.02	-	1	3.0000	-	1
24	40	1.47	0.2280	10	4.4000	0.8000	10
8 July	54	1.71	0.1945	25	5.2000	0.4000	25
22	68	2.10	0.4197	26	5.9615	0.5871	26

Discussion

The graphs (Figs. 9, 10, 11, and 12) show the different rates of development for the different varieties of *Mitopus*.

M. morio and *M. morio alpinus* develop at almost exactly the same rate, i.e. in the graph of mean instar to date the gradient in both cases is 0.75. In the other graphs of mean femur length to date the gradients are the same but *alpinus* is larger throughout its life history. It also hatches and matures later. It is however still

Fig. 9 Log Mean Femur Length against Date

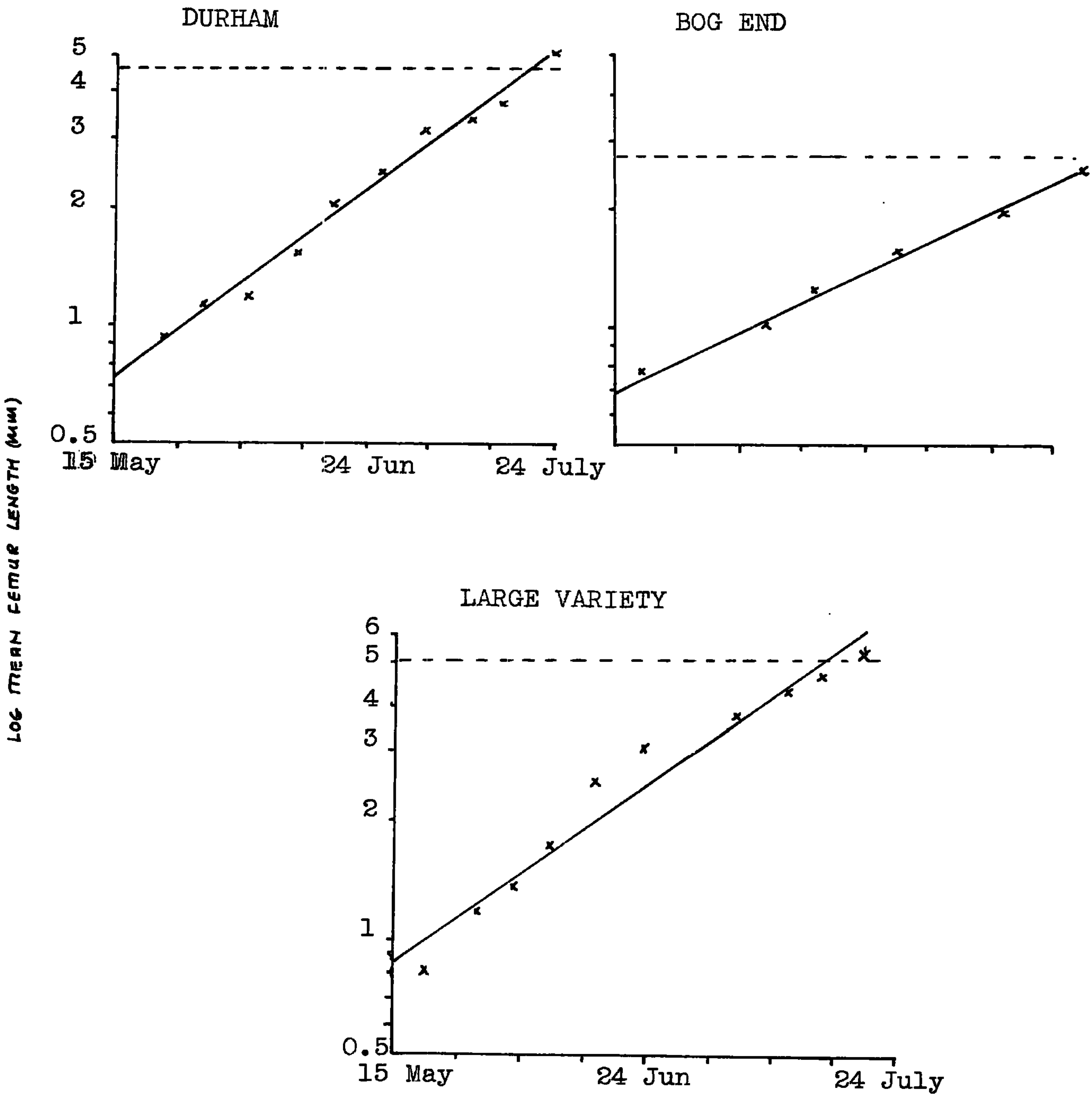


Fig. 10 Mean Femur Length against Date

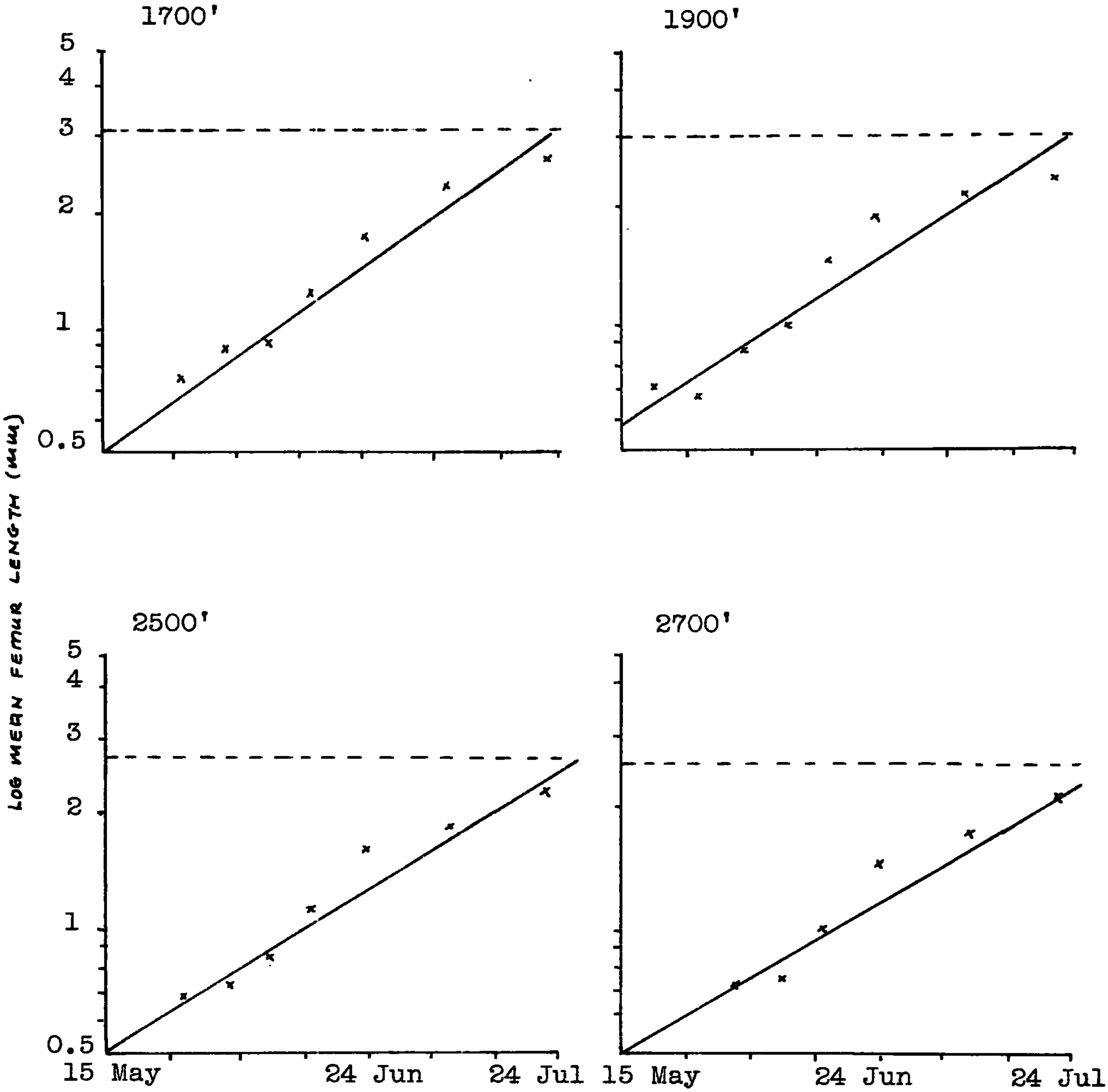


Fig. 11 Mean Instar against Date

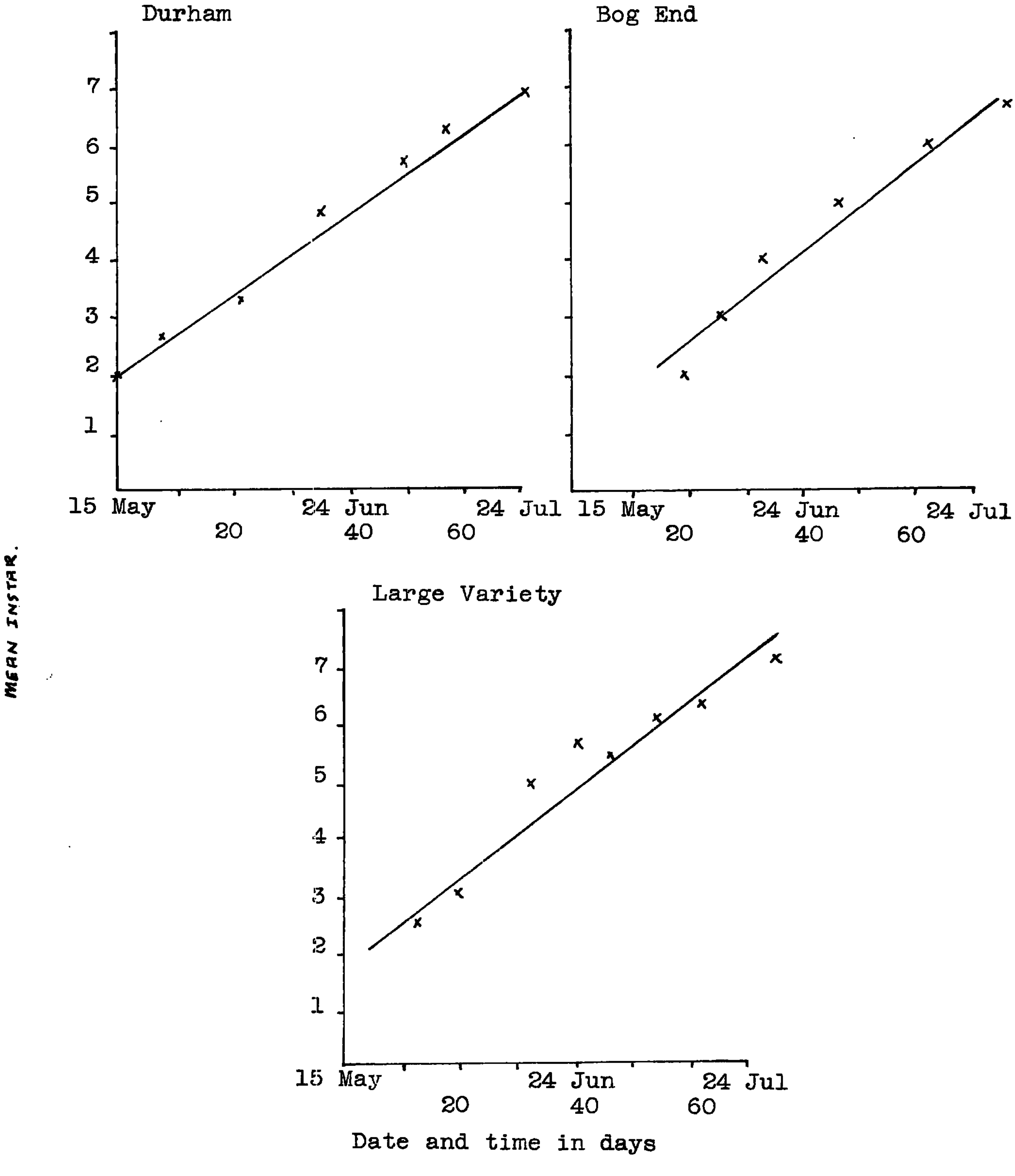


Fig. 12 Mean Instar against Date

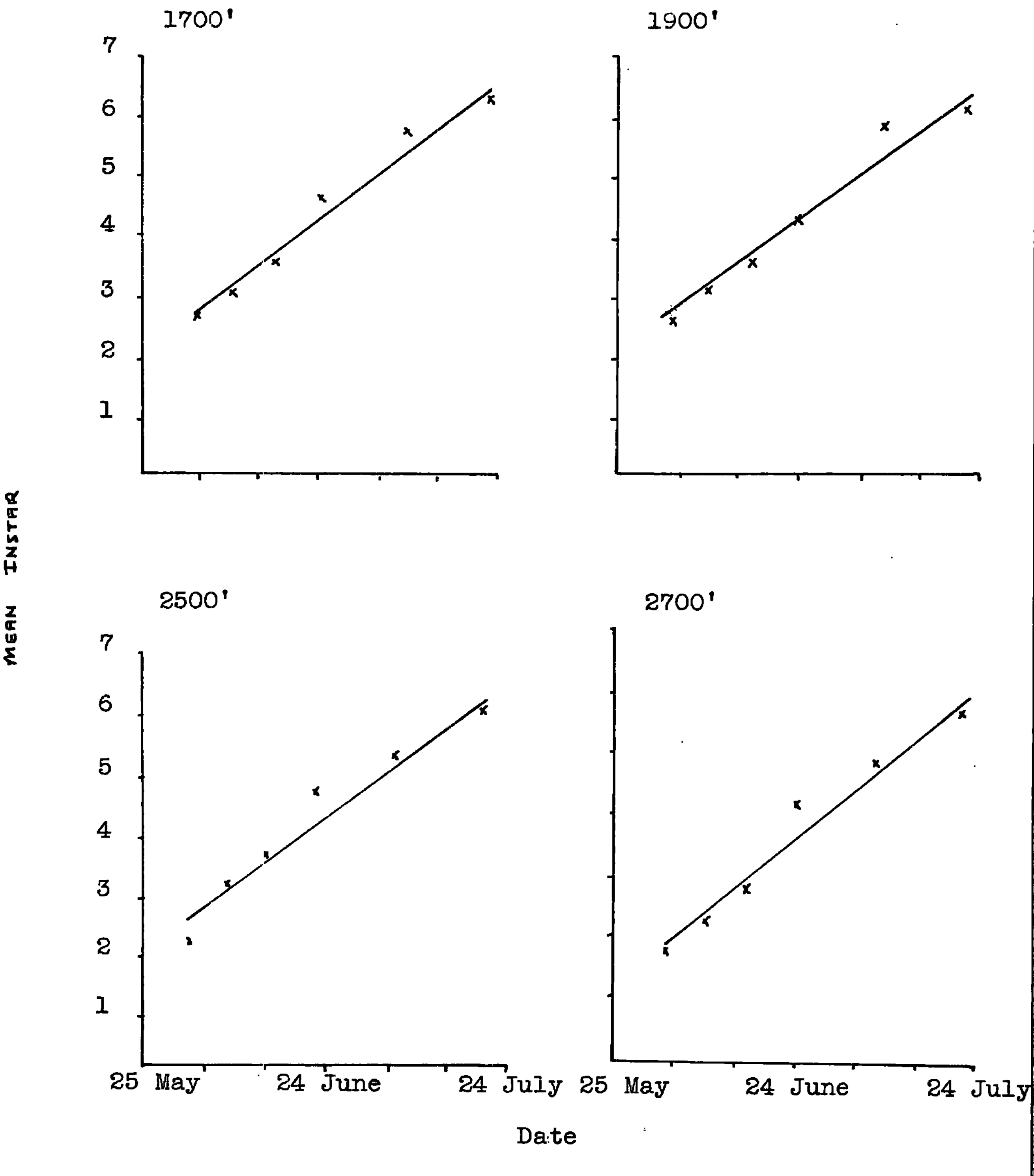
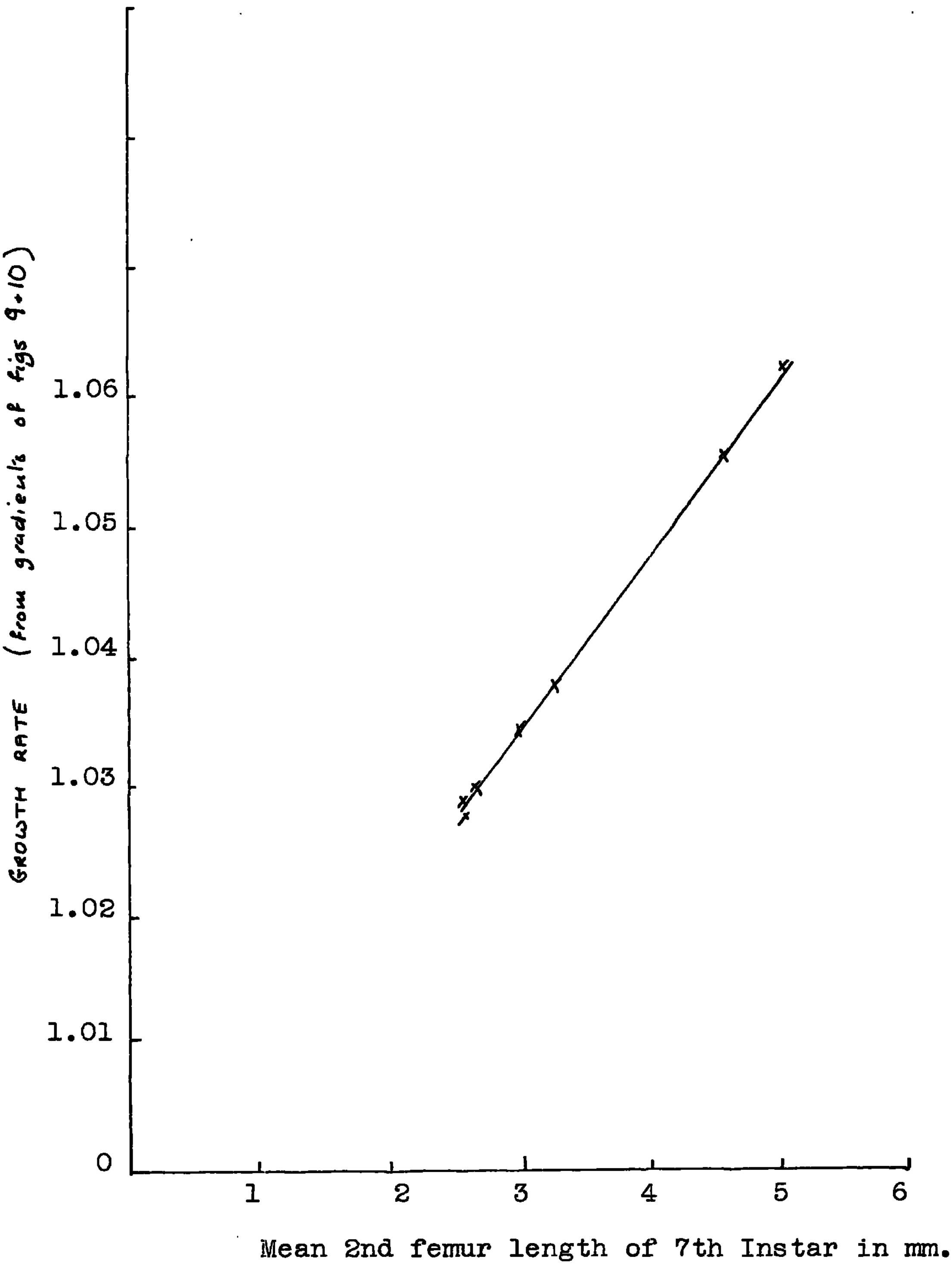


Fig. 13 Mean 7th Instar against Growth Rate



mature by the end of July and capable of ripening its eggs and laying them before the weather deteriorates seriously in late September or early October.

M. morio cinerascens shows a deceleration in growth rate with increase in altitude up Dun Fell. At Bog End it seems to have a life history more equivalent to 2500 or 2700 ft. on Great Dun Fell. Its adults are almost the same size as those of 2700 ft. (2.6mm mean 2nd femur length).

It appears from the graphs that cinerascens grows at a very much slower rate than alpinus but this is just due to the fact that it develops in the same time but to a much smaller size. This is shown clearly by the graph (Fig. 13) of growth rate to mean second femur length of the seventh instar. It suggests that the rate is predetermined and depends entirely on the size to be reached during the time of development. But why is there such a size difference? It may be because of an exploitation of different food sizes.

The deceleration effect on Great Dun Fell is probably due to a decrease in temperature and an increase in rain when they do not venture out in search of food. (see Chapter IV(d)) All the graphs (Figs. 9, 10, 11 and 12) show an increased development rate during June, a very fine, hot month.

Much more work needs to be done before the questions arising here can be answered. Does the rate of growth vary slightly or greatly each year? Was 1969 an exceptional year in that everything was late in hatching but had a good start from the extremely fair early summer?

The differences in development rate must be differences in metabolic rate and this factor was investigated in the following chapter.

IV (c)

RESPIROMETRY

IV (c) RESPIROMETRY

After finding the different growth rates of the varieties of Mitopus and knowing the climatic differences between Durham and Moor House, a difference of metabolic rate would be expected. In fact it should be higher in the Moor House forms. The only method available to study this was to measure the uptake of oxygen using Warburg respirometers.

Method

The amounts of oxygen used by M. morio cinerascens and M. morio in a known time were measured using Warburg manometers. The principles of the apparatus are comprehensively described in Umbreit (1957).

Ten millilitre flasks were calibrated by the ferricyanide hydrazine method (Umbreit 1957) which for given concentrations and amounts liberates a known amount of gas so that the volume of the flask and manometer tube can be calculated.

The animals (of known weight), five in the case of cinerascens and two in the case of morio, were placed in the flask with 0.1ml of 10% KOH in the centre well to absorb carbon dioxide. The apparatus was checked for leaks and put in a water bath at 15°C to equilibriate for twenty minutes. All the taps remained open.

The fluid was then levelled at 150 and the taps closed; the open limb was then read. At the same time a thermobarometer had been set up to measure any pressure changes in the room. This is exactly the same as the other Warburg manometers but has no animals in.

Every ten minutes the closed arm was returned to 150 and the level of the open arm read. This method keeps a constant volume of gas in the flask and therefore is a measurement of pressure change. Allowances are made for the thermobarometer changes. The apparatus was run for about two hours with five manometers at a time. The readings give the h value used in the calculation of the amount of O_2 used.

$X = hk$ where X is the volume of O_2, h is the reading on the manometer and k is the constant obtained from

$$k = \frac{Vg \times 273/T + Vf \times \alpha}{P_o}$$

where Vg is the volume of the flask (calibration) T is the temperature in $^{\circ}$. Vf is the volume of fluid used, α is the coefficient of absorbtion of the gas and P_o is the pressure of manometer fluid 10,000. When using animals Vf and α are ignored.

The results are given in mm^3/mg/hr.

Results

Table 18. The Mean O_2 Consumption in $mm^3/mg/hr$.

Variety	Mean	SD	N	Difference factor
M. morio from Durham	0.2113	0.0669	15	1.762
M. morio cinerascens from Moor House	0.3677	0.0401	5	

Discussion

These results at first look extremely low but they have a difference factor of 1.762 which is of the order expected from the facts of their developmental rate and the different climates. But Phillipson (1962) when using his own continuous recording respirometer obtained the following results for Mitopus morio (in $mm^3/mg/hr.$).

1st period		2nd period	
Day	Night	Day	Night
0.626	0.796	0.654	0.814

These are twice and three times as fast as the above results. However there is a possible answer. MacFadyan (1961) when trying out a continuous respirometer found that Platybunus triangularis (Herbst 1799), another harvestman, after four days reduced its respiratory rate to 0.2 $mm^3/mg/hr$ although still alive.

None of the above results were from animals that had only just been captured so perhaps the same thing had occurred.

Respirometry is very important in ecological studies as it gives an idea of metabolic rates, but the Warburg respirometer is not accurate for anything respiring below a rate of 10 mm^3 O_2 per hour. Other methods should therefore be tried as they can be more accurate for small animals and should be looked into. A selection are the Katharometer (Stiles and Leech 1931), Pettenkofer tubes (James and James 1940), closed systems and infra-red gas analysis (Mooney and Billings 1961) or the continuous respirometers of Tuft (1950), MacFadyan (1961) and Phillipson (1962), and most of these are designed for things respiring at a rate of 0.01 to 5.0 1 of O_2 per hour.

IV (d)

CULTURES

Plate IV

Great Dun Fell 2500' Site

Great Dun Fell 2700' Site

IV (d) CULTURES

(i) Materials and Methods

Durham

Young specimens were obtained from beech and oak litter on the University field station. Handfuls of leaves were shaken on to a white sheet. After a few moments the harvestmen began to move and could be easily collected.

Later instars were easier to catch by searching among the grass and litter, where they could be seen moving about.

All the specimens were taken back to the laboratory and placed into individual cultures. These were set up using petri dishes containing a floor of damp filter paper. The food tried at first was varied, but freshly killed blowfly larvae or pupae were soon found to be preferred.

Each animal was fed and watered daily and daily records of their condition were made, especially the times of moulting and death.

The early instars were very difficult to keep alive as they seemed rather susceptible to humidity changes. However, after the third instar they lived quite well and for long periods.

Some cultures were kept in the laboratory where the temperature varied with the outside weather. It was perhaps higher than the animals were used to in the field. Others were put in the 10°C cold room. The same treatment was given to both.

Moor House

Unfortunately, live specimens were extremely difficult to find on Moor House and cultures of these were started late on in the proceedings. They hid well down in the *Sphagnum* or *Polytrichum* when the weather was cold or wet. This was probably drier and a few degrees warmer than the surrounding air. On days when it was warm and dry they ran over the moss and along the woody stems but as soon as one attempted to catch them they dropped off into the *Sphagnum* and, due to their excellent camouflage, were difficult to see until they started moving again.

However some were caught when they were fifth or sixth instars and therefore the number of moults they went through in culture were small. They were put in cultures exactly like those caught in Durham and some placed in the 10°C cold room, others in the laboratory.

All the Moor House specimens were from Bog End and none of the large variety were kept.

If an animal died in culture the length of the femur of its second leg was measured and then the animal was put in 70% alcohol. This measurement was made in order to determine the instar by the method shown in Chapter IV(a).

If an animal reached maturity it was killed and the same measurement was made before placing it in alcohol.

Results

After all the animals in the cultures had died or been killed the numbers of days between each moult were determined. The means, standard deviations and errors were calculated for the four different sets of cultures which were:-

(1) Durham specimens cultured in the laboratory
(2) Durham specimens cultured in the 10°C cold room
(3) Moor House specimens cultured in the laboratory
(4) Moor House specimens cultured in the 10°C cold room

Table 19. Showing the Mean Intervals in Days between the different Sets of Cultures.

Specimen				
origin	culture	mean	SE	SD
Durham	laboratory	8.7500	0.5607	2.5075
Durham	cold room	23.1818	0.6005	1.9917
Moor House	laboratory	8.0000	-	-
Moor House	cold room	22.8000	0.7155	1.6000

Students t-tests were carried out giving the following results.

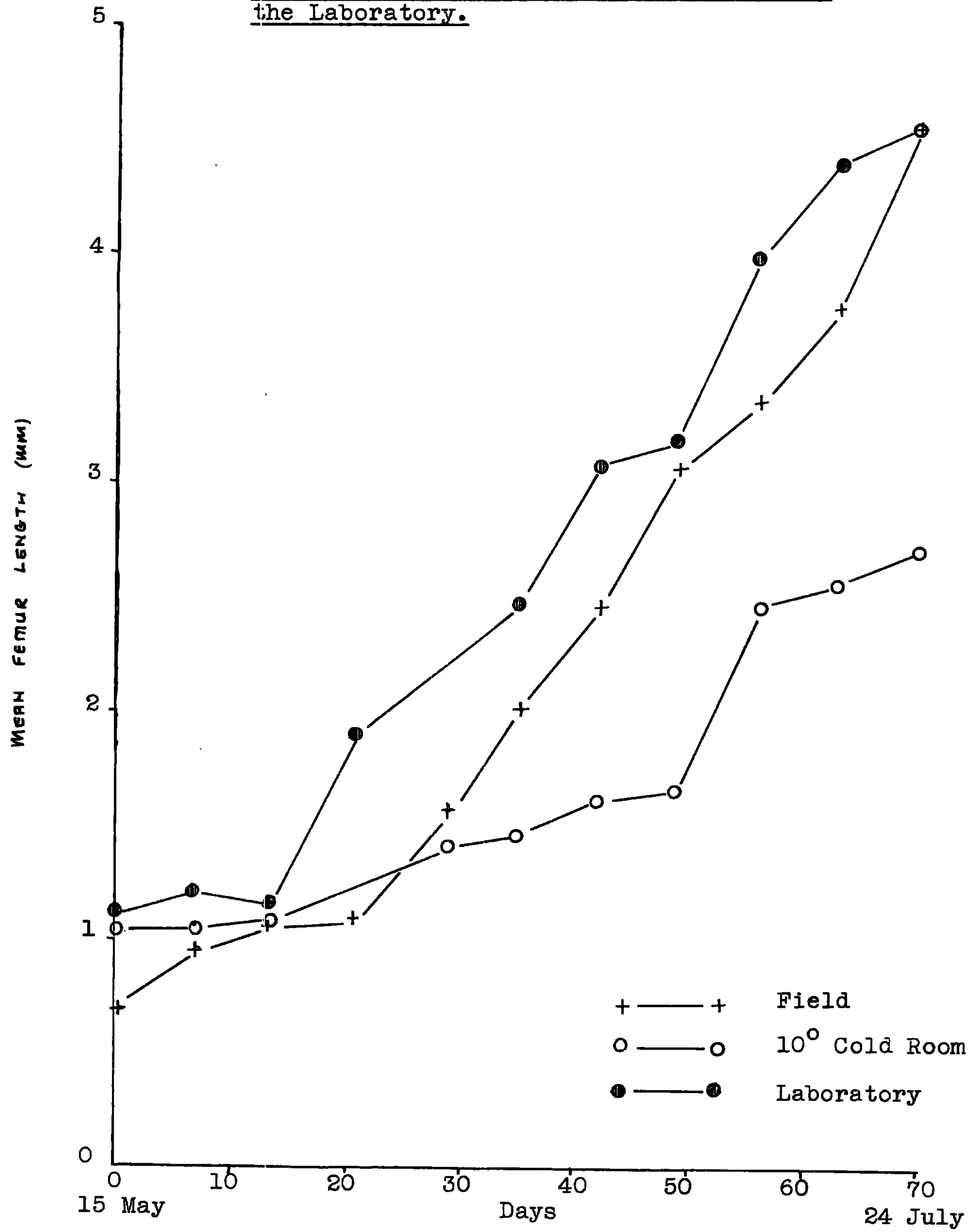
Table 20. <u>Showing the Results of t-tests on the Mean Intervals (days) between Moults.</u>

Between		t	°f	p
Durham lab.	Durham c.r.	17.5660	29	<0.001
Moor House lab.	Moor House c.r.	20.6848	8	<0.001
Durham lab.	Moor House lab.	1.3376	21	>0.1
Durham c.r.	Moor House c.r.	0.4370	14	>0.1

Table 21. <u>To Show the Difference between the Mean Femur Length of the 2nd Leg in Specimens from Cultures and Field Collections.</u>

Date	Field	SE	lab. culture	SE	10°C culture	SE
<u>DURHAM</u>						
May 15th	0.73	0.0193	1.0867	0.0331	1.1300	0.0071
23rd	0.92	0.0663	1.1983	0.0608	1.1300	0.0071
29th	1.11	0.0968	1.1400	0.0414	1.1400	-
June 5th	1.14	0.0836	1.8767	0.2711	-	-
13th	1.53	0.0537	2.1900	0.2475	1.4450	0.0530
19th	2.02	0.0678	2.4500	0.1812	1.4450	0.0530
26th	2.46	0.0216	3.0983	0.4296	1.5633	0.1579
July 3rd	3.07	0.0854	3.1900	0.5056	1.6600	0.2051
10th	3.34	0.0116	3.9975	0.4341	2.4700	0.3499
17th	3.71	0.1921	4.4156	0.2434	2.5675	0.2757
24th	4.51	0.1653	4.5225	0.1662	2.7186	0.1468
<u>MOOR HOUSE</u>						
July 16th	1.90	0.0357	1.9500	-	1189	0.1626
29th	2.48	0.0539	2.4220	0.1271	2.09	0.0384

Fig.14. To Show the Growth Rate of Durham Specimens in the Field and Cultures at 10°C and in the Laboratory.



From the measurements of the femur of the second leg the mean femur length for each week was determined so that it could be compared with those found in the field (see Table 21).

Discussion

The fact that there is such a great difference between the moulting intervals in the 10°C room and the laboratory suggests that the metabolism of M. morio is affected markedly by temperature. That the individuals from Moor House did not differ from those of Durham under the same conditions seems to indicate that either they are affected by low temperatures in just the same way, or that 10°C is below the critical temperature at which Mitopus really begins to develop properly. The latter is the more likely answer as the former would mean that it would not be able to develop fully on Moor House. The fact that it does complete its life history successfully there, however, indicates that it probably has a critical temperature somewhere just above 10°C and therefore makes use of any temperatures above that.

The growth rate shown by the femur lengths further indicates that temperature affects the metabolic rate. The graph Fig. 14 shows that the Durham specimens had a much slower growth rate when cultured at 10°C.

The fact that the laboratory results seem to show a faster growth rate than in the field may be misleading. The field population had new individuals hatching into it over a period of several weeks whereas the cultures did not. However, new cultures were started at frequent intervals which should have cancelled out that problem. It may have been that it was a direct effect of higher temperature that gave the faster growth rate.

That temperature does affect the growth rate is further substantiated by the fact that the growth rates for Moor House shown in Figs. 9 & 10 all show a steep rise in June when the weather was extremely hot.

These ideas need confirmation from much more experimentation to determine the critical temperatures at which hatching and growth occur, the lethal temperatures both high and low for the different stages in the life history, and from these estimations of thermal sums could be made for Moor House and Durham M. morio.

V

GENERAL DISCUSSION

V GENERAL DISCUSSION

Nobody has worked on the biology of highland forms of M. morio, although Todd (1949), Phillipson (1959, 1960a, 1960b, 1962) and Heighton (1963) had studied different aspects of the lowland form.

It was decided to carry out a comparison of the life histories of the lowland forms around Durham and the highland forms found at Moor House. It was thought that as they were the same species they would be genetically and physiologically alike and the study was carried out to determine how those on Moor House could complete their life histories in a colder, wetter climate.

However, the highland forms were found to be described varieties of M. morio known as cinerascens and alpinus. But this separation into different varieties was only made after they had been already separated statistically by using the ratio of femur length to width against length.

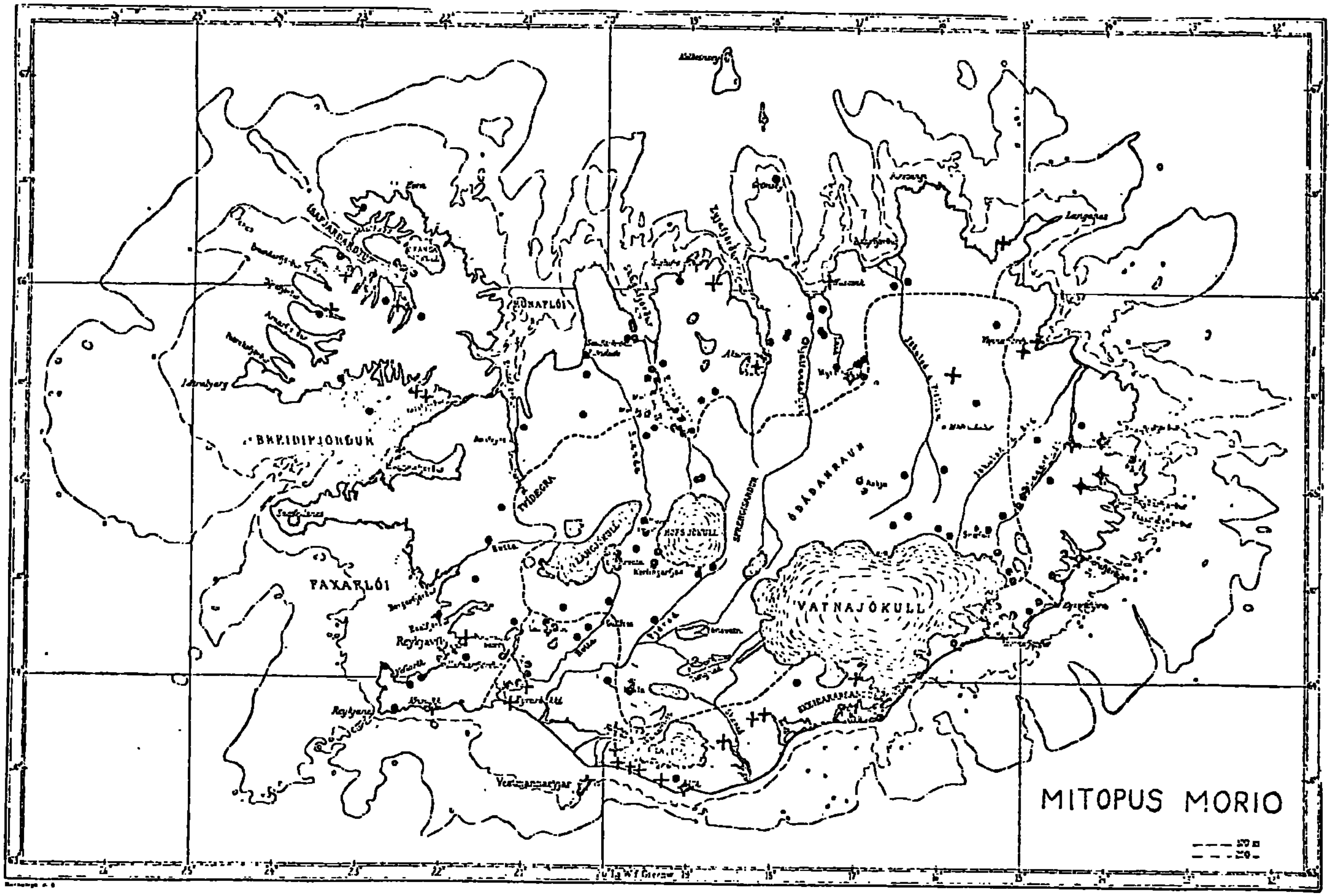
The fact that the Mitopus on Moor House were different varieties made the study more difficult as they were clearly physiologically and genetically different forms although the same species.

The three varieties have not been well described and are only mentioned in a few papers, Hull (1926, 1930) and Savory (1948). The most comprehensive description is that of Pickard - Cambridge (1890). It is now seventy years since that work was published and a full, up to date description of British harvestmen is sorely needed.

This study has shown how much more work is needed on the forms of Mitopus at high altitudes. It has produced many problems. Why do alpinus and cinerascens only live at high altitudes and morio only at low altitudes in Britain? In Iceland, the southern part of which has a similar climate to Moor House (Manley 1936), Mitopus are found all over the island from the seashore to the tops of the mountains (Henriksen 1938). Are the Mitopus there all alpinus and cinerascens or do they have a similar distribution to Britain with Mitopus morio in the lowlands?

Do alpinus and cinerascens overlap completely in their distribution? They can probably live together on Moor House because they have different ranges in the size of the food they exploit and no competition occurs. This is probably why cinerascens is more numerous as the smaller food which it eats such as Collembola is more common than larger animals which would be the food of alpinus.

This could also be the reason why cinerascens and



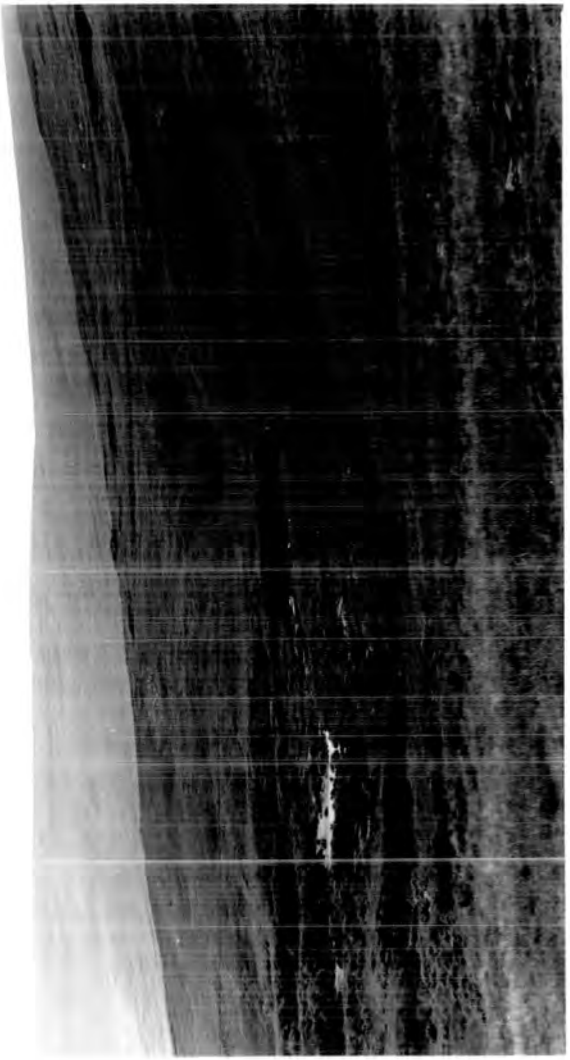
Map showing the distribution within Iceland of *Mitopus morio*.

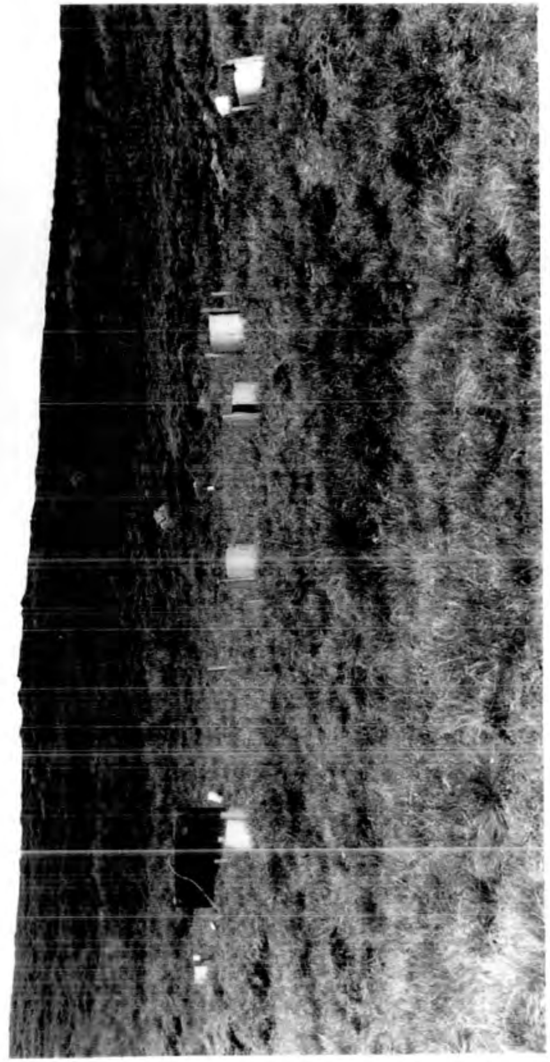
alpinus seem restricted to highland where no other common harvestmen occur. _Alpinus_ is probably replaced by a more efficient _morio_ in the competition for larger food and _cinerascens_ by smaller species of harvestmen more efficient in the lowland environment. The Iceland problem should help in this question. If this is the reason for _alpinus_ and _cinerascens_ living on highland, in Iceland where _Mitopus_ is the only common harvestman they should be common in the lowlands as well.

More work needs to be done on the growth rate to find out whether it is predetermined with a small amount of annual variation or whether it varies a lot each year. The former is the more likely explanation, with some kind of mechanism to allow for the annual variation in climate.

The fact that the growth rate is determined directly by the size of the animal was shown (see Fig. 13). This is very interesting as it means that whatever the size, maturity has to be reached in a certain period, so the larger the animal the faster the growth rate. But why does _morio_ from Durham fit in with the varieties on Moor House which have such a short season?

It is interesting that _alpinus_ has the same growth rate as morio although it is at such lower temperatures.





This must be a product of its different genetical and physiological make up.

More data are needed to find out exactly what the effect of temperature is and where its lethal limits are. What is the optimum temperature? Is it the same or different in the different varieties?

The respiratory rate was shown to be different in *morio* and *cinerascens*. This was expected from the difference in climate and other factors. It would be expected that *alpinus* would also be different. The diurnal variation and instar variation of respiratory rate ought to be examined in the different forms.

All in all this study has brought many problems to light but owing to its brevity has only just scratched the surface of an extremely interesting subject.

VI

SUMMARY

VI SUMMARY

The life histories of *Mitopus morio* at sites at Durham and Moor House were compared to find out whether the difference in climate affected them.

As an outcome of the study three varieties of *Mitopus morio* were found, *morio*, *alpinus* and *cinerascens*, the last two found only on upland areas.

The instars were separated using the length of the femur of the second walking leg and the growth rate was determined.

These growth rates were found to vary with the different varieties but directly in relation to the size of the animal.

As would be expected, from the colder climate, the respiratory rate of *cinerascens* was found to be higher than that of *morio* and temperature was shown by cultures to have a marked effect on the growth rate.

VII

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VIII

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