A study of the activity of six species of harvest – spiders (arachnida, opiliones)

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A STUDY OF THE ACTIVITY OF SIX SPECIES OF HARVEST - SPIDERS (ARACHNIDA, OPILIONES).

by

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Being

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C O N T E N T S

I. INTRODUCTION

I INTRODUCTION

Elton's much quoted statement that animals spend a great deal of time doing nothing (Elton 1927) must apply to periods when conditions are favourable for activity or the statement is a simple tautology. Williams (1959) agrees with this thesis when he showed that woodland invertebrates produced a more uniform distribution of locomotor activity that in scrubland. This he attributed to the provision of extra food and not simply to the more stable microclimate. Williams states further (1962) that the more restricted periods of activity have been found in the habitats in which the animal is most abundant, and so presumably the habitat which is most favourable to it.

Does this mean that if an animal has a marked nocturnal or diurnal activity then it is not an unfavourable locomotor factor that is restricting it during inactive periods but some other factor, such as lack of food, that is making activity worthless?

Greenslade (1963) showed that the predatorial Carabidae are either nocturnal or diurnal but never exclusively crepuscular. The nocutrnal behaviour of harvest-spiders (Arachnida, Opioiones) has long been known (Pickard - Cambridge, 1890; Todd, 1949). Todd's work (1950) showed that harvest-spiders are important predators in the habitats they occupy and it is possible that their activity is a function of their feeding. Authors before Immel (1953) implied that harvest-spiders were active hunters, but Immel showed that Nemastoma quadripunctatum did not respond to food until physical contact had occurred.

Two previous works have dealt with the subject of activity in harvest-spiders (Heighton, 1964; Williams, 1962), only Williams carried out experiments in the field, using pitfall traps and population estimates, while Heighton confined his experiments to three species in the laboratory by making use of an aktograph.

The present study was designed to investigate the activity of harvest-spiders under field conditions and particularly to compare the activity of individual species and immature stages of different sizes (instars). The work was carried out from April to July 1970 in the Zoology Field Station, Hollingside Lane, Durham.

II MATERIALS AND METHODS

II(a). THE SPECIES

II(a) The Species

Throughout the study the following species were encountered:

FAMILY PHALANGIIDAE

Sub Family LEIOBUNINAE

Leiobunum blackwallii (Meade)

**Leiobunum rotundum* (Latreille)

Sub Family OLIGOLOPHINAE

**Lacinius ephippiatus* (C.L. Koch)

**Mitopus morio* (Fabricus)

Oligolophus agrestis (Meade)

**Oligolophus tridens* (C.L. Koch)

Odiellus palpinalis (Herbst)

Sub Family PHALANGIINAE

Phalangium opilio (Linnaeus)

**Platybunus triangularis* (Herbst)

FAMILY NEMASTOMATIDAE

**Nemastoma chrysomelas* (Hermann)

Nemastoma lugubre (Müller)

Only the common species (marked with an asterisk) were used; the data collected for the other species appears in the Appendix.

The methods used by Heighton (1964) to isolate the instars of each species has been used (Section III), while the Key produced by Todd (1948) was the main source of reference for adults.

II(b) THE STUDY SITE

II(b) The Study Site

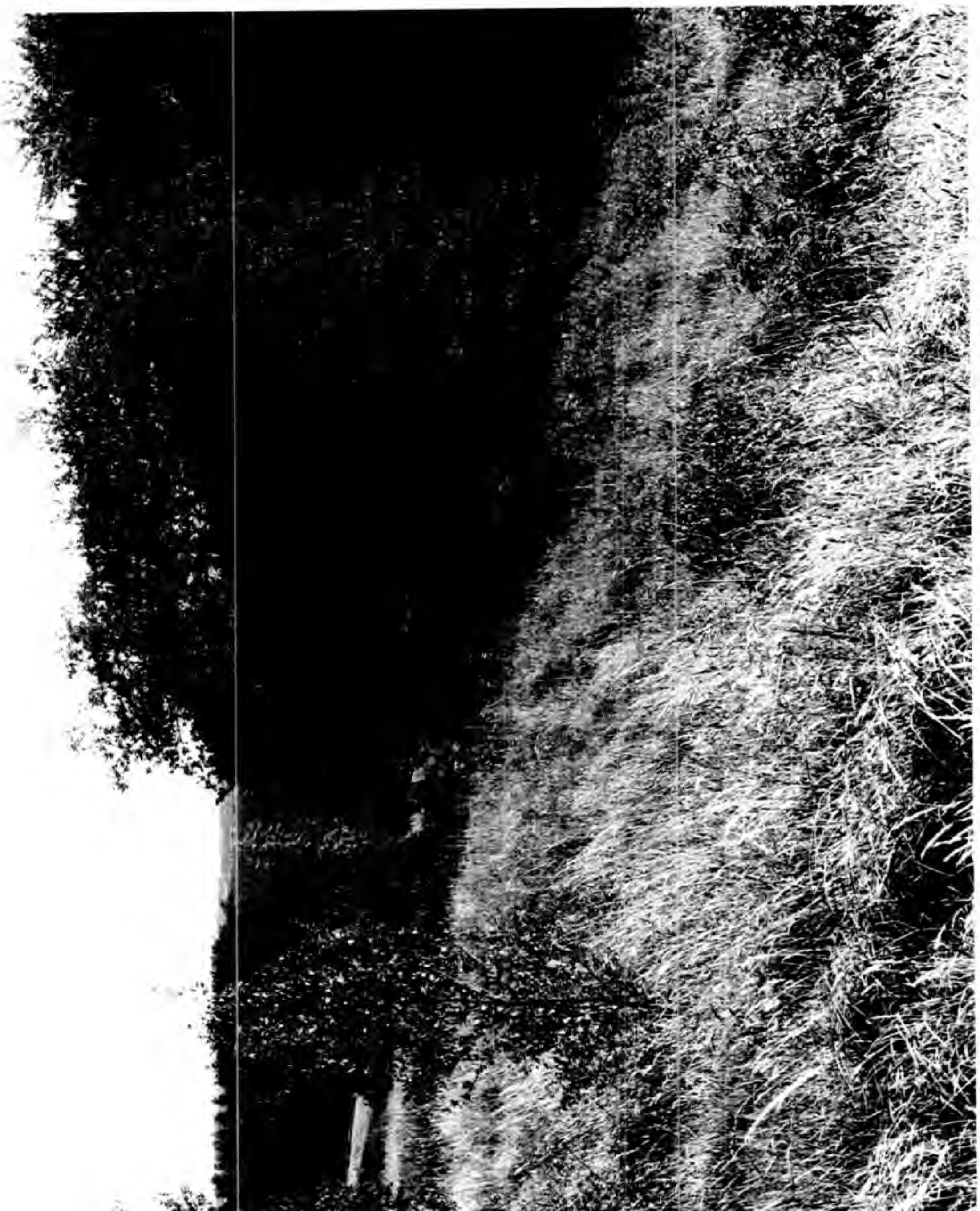
The entire study was carried out at the Zoology Field Station, Hollingside Lane, Durham (Nat. Grid. Ref. NZ.274406). An area of 640 square metres on a West South West facing slope of ungrazed pasture was chosen for the study (Plate 1). The soil type was brown earth overlying coal measures at an altitude of 250 feet above sea level.

The dominant vegetation was that of Cocksfoot grass (*Dactylis glomerata* L.), but the following plants were also present and their frequency denoted by the usual letters a. (abundant), f. (frequent), and o. (occasional) ......

(a)	*Lolium perenne* L.	Rye grass
(f)	*Achillea millefolium* L.	Yarrow
(f)	*Potentilla erecta* L.	Common Tormentil
(f)	*Plantago lanceolata* L.	Ribwort plantain
(f)	*Phleum pratense* L.	Timothy
(f)	*Holcus lanatus* L.	Yorkshire Fog
(o)	*Rumex acetosa* L.	Common sorrel
(o)	*Geranium pratense* L.	Meadow cranesbill
(o)	*Lotus corniculatus* L.	Bird'sfoot trefoil
(o)	*Veronica agrestis* L.	Field Speedwell
(o)	*Rubus* sp. L.	
(o)	*Deschampsia cespitosa* L.	Tufted Hair grass
(o)	*Festuca ovina* L.	Sheep's Fescue
(o)	*Crataegus monogyna*	Jacq. Hawthorn.
(o)	*Quercus robur* L.	Oak
(o)	*Betula pendula* L.	Silver Birch
(o)	*Chamaenerion angustifolium* L.	Rose Bay Willow Herb
(o)	*Senecio squalidus* L.	Oxford Ragwort

P L A T E 1

Zoology Field Station showing study site



Meteorological Data

Durham University Observatory, ½ mile from the field station, supplied the figures for maximum and minimum temperatures and rainfall for the duration of the study. These appear in Fig. 1.

Time Periods

For convenience the study period from 29 April to 29 July 1970 was divided into three, corresponding approximately to the months May, June and July. The sampling dates throughout these periods appear below.

PERIOD	sampling dates for quadrats	Sampling dates for pitfall traps
1 29April-27May 1970	4, 19 May	6,13,20,27 May
2 28May-24June 1970	1, 15 June	3,10,17,24 June
3 25June-29July 1970	30 June, 20 July	1,8,29 July

Table 1. Division of time for study period from 29 April - 29 July 1970, and sampling dates for quadrats for population estimate and pitfall traps.

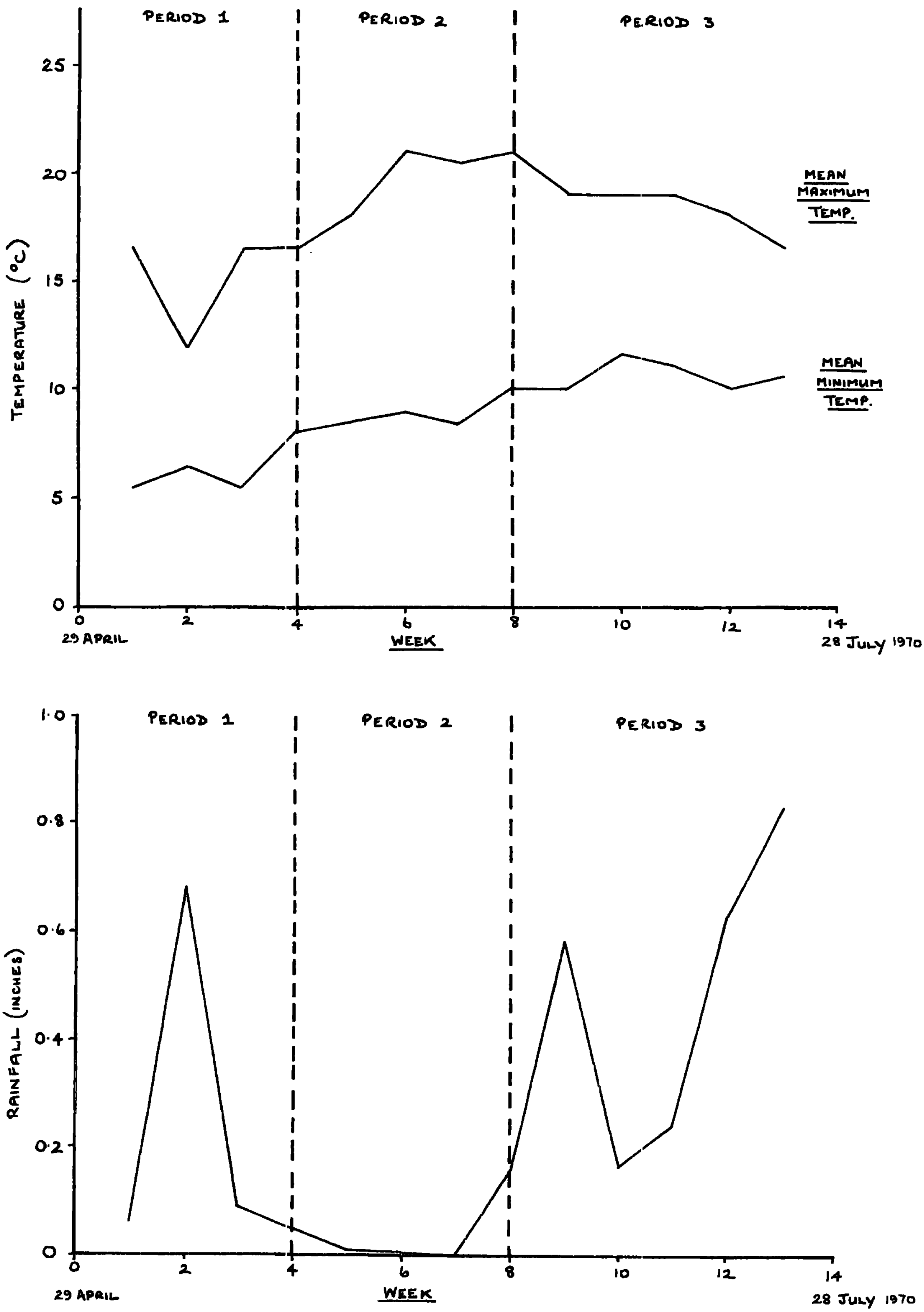


Fig. 1 Mean Maximum + Minimum Weekly Temperatures (°C) and Total Weekly Rainfall for period 29th April-28th July 1970 for Durham. Periods 1,2,3 refer to divisions of study period (see Table 1)

II(c) COLLECTION and SAMPLING METHODS

II(c) Collection and sampling methods

Fourty pitfall traps were put down in late April in an area of ungrazed pasture of 640 square metres. Each trap was placed four metres apart in five rows of eight, each row was similarly placed four metres apart. The traps, one pound jam jars (diameter 5.5cm. and 11cm deep), were sunk into the ground so that their rims were level with the soil surface. Each was half filled with a dilute soap solution to which had been added a few drops of formalin. Throughout the study the traps were emptied weekly except for periods of the diel study (see Section V) when for five days they were emptied at six hourly intervals. During this time the individual catches were added to the total weekly catch which had been correspondingly depleted. Date, trap number, species, instar and sex if adult, was recorded for each individual collected from the pitfall traps. All specimens were stored in 70% alcohol with a trace of glycerine added (Sankey, 1949a).

Every two weeks, on the dates shown in Table 1, ten samples of 25 x 25cm quadrats were taken from the study area to estimate the population of the various species. Each sample was selected by use of random tables, and on a stratified system such that of the ten selections two were from each of the five rows.

At first the quadrats were cut using a spade only. As it was conceivable that some harvest spiders could leave the area as the sample was being cut a special piece of apparatus was devised. This consisted of four metal sheets each 60 cm. long and 25 cm. wide and having two steel pins 45 cms long to secure its position in the ground. Having selected the sample site the sheets were arranged such that a 25 x 25 cm quadrat was enclosed by their walls. (Plate 2) Any specimens within the field layer (Elton & Miller, 1954; Sankey, 1949a).

could be hand collected and stored before the cutting procedure began. Each sample quadrat consisted of a thin soil layer of less than 3cm together with the ground layer including any litter, and the field layer of grasses and other small plants. This was placed in a large polythene bag, labelled and put into a Berlese funnel for 2 days. Each funnel was supplied with a 60 watt bulb placed 30 cm. above the sample and the temperature of 30°C was maintained throughout.

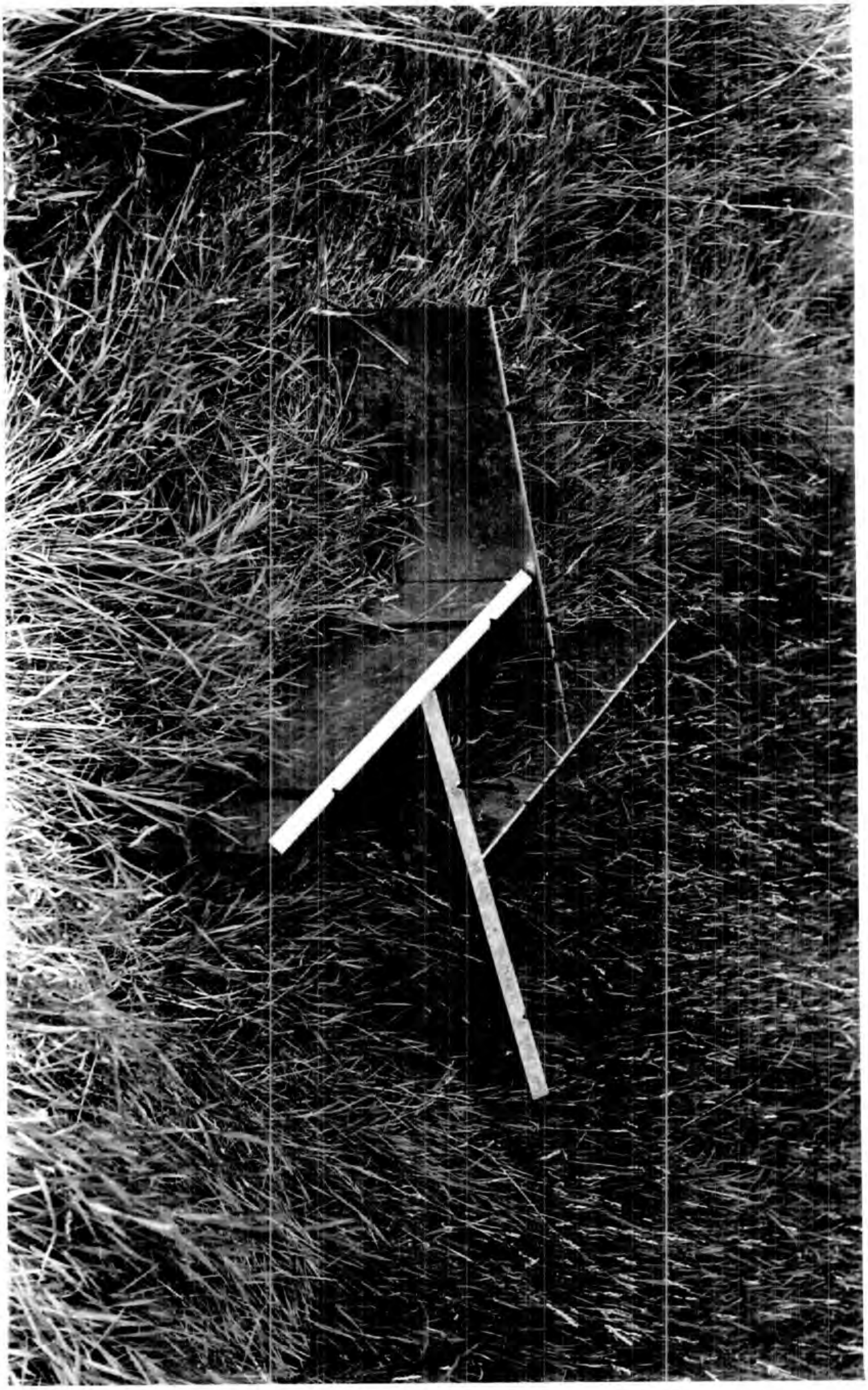
In a prelimary study this method did not seem to extract the specimens well and it was possible that the heat drove them further into the soil from the above ground vegetation. On investigation of the dried litter and soil dead harvestmen were found,and similarly on introducing marked specimens they were not found to reappear in the solution below the funnel but were trapped in the deep litter and died. This was overcome by placing the quadrat sample on its side in a vertical position and spreading the loose vegetation, thus allowing lateral migration.

At the end of Period 1, when later instars were encountered, each sample was hand sorted after collection and then placed into the Berlese funnel. Each sample was sorted twice on a large light coloured sheet of polythene, the larger specimens were caught using this method while the heat extraction tended to force out the early and thus smaller instars.

All specimens were identified by species and instar, and stored in 70% alcohol and glycerin.

P L A T E 2

The Variable quadrat used for population estimates



III IDENTIFICATION & DETERMINATION OF INSTARS

III IDENTIFICATION AND DETERMINATION OF INSTARS

As neither Falconer's (1910) nor Todd's (1948) key to the British Harvestmen refers to the instars of the individual species and although it was possible to use the latter key for the early stages in some cases, since they differed little from the adults, it was necessary to use Heighton's adapted key for the identification of the instars of the Sub-family Oligolophinae.

Heighton's technique for instar determination was also used. This was carried out by measuring the femur of each of the second legs of every specimen by means of a micrometer eyepiece previously calibrated against a scaled microscope slide.

For the six most common species encountered and those which form the basis of this study measurements of femur length of the second walking leg are shown as frequency distributions. (Figs. 2-7)

In no species was the first instar caught in the pitfall traps or collected from the Berlese funnel extractions. This was apparently due to the fact that the first moult takes place shortly after emerging from the egg and thus all the information collected refers to specimens from the second instar to the adult. In all cases, except possibly Leiobunum rotundum, each species passes through six instars before the final moult into the adult.

It can be seen (Figs. 2 & 3) that there is some overlap in certain species between the sixth and adult instars. It was possible to show this by examining the genital plate which is open in the adult. No similar feature could be used for the earlier instars and so it was impossible to prove an overlap existed in these, although it may occur.

The peculiar bimodal distribution for Leiobunum rotundum in instars six and seven (Fig. 3) was investigated. By producing a graph of log mean fumur length against instar for instars II - V it was possible to predict the femur length of the sixth instar and adult (Fig 8)

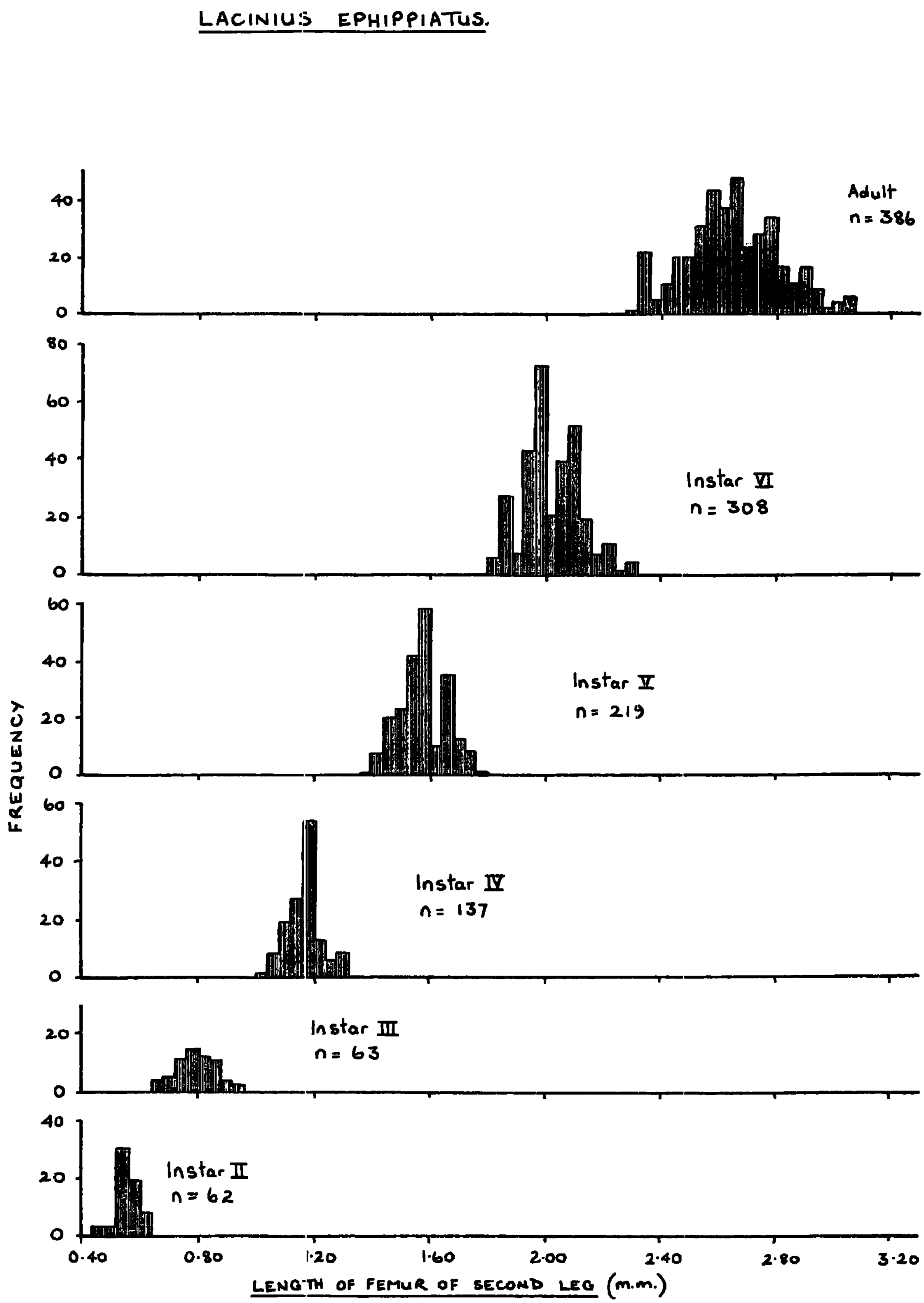


Fig. 2 Frequency distributions of second femur length of Lacinius ephippiatus.

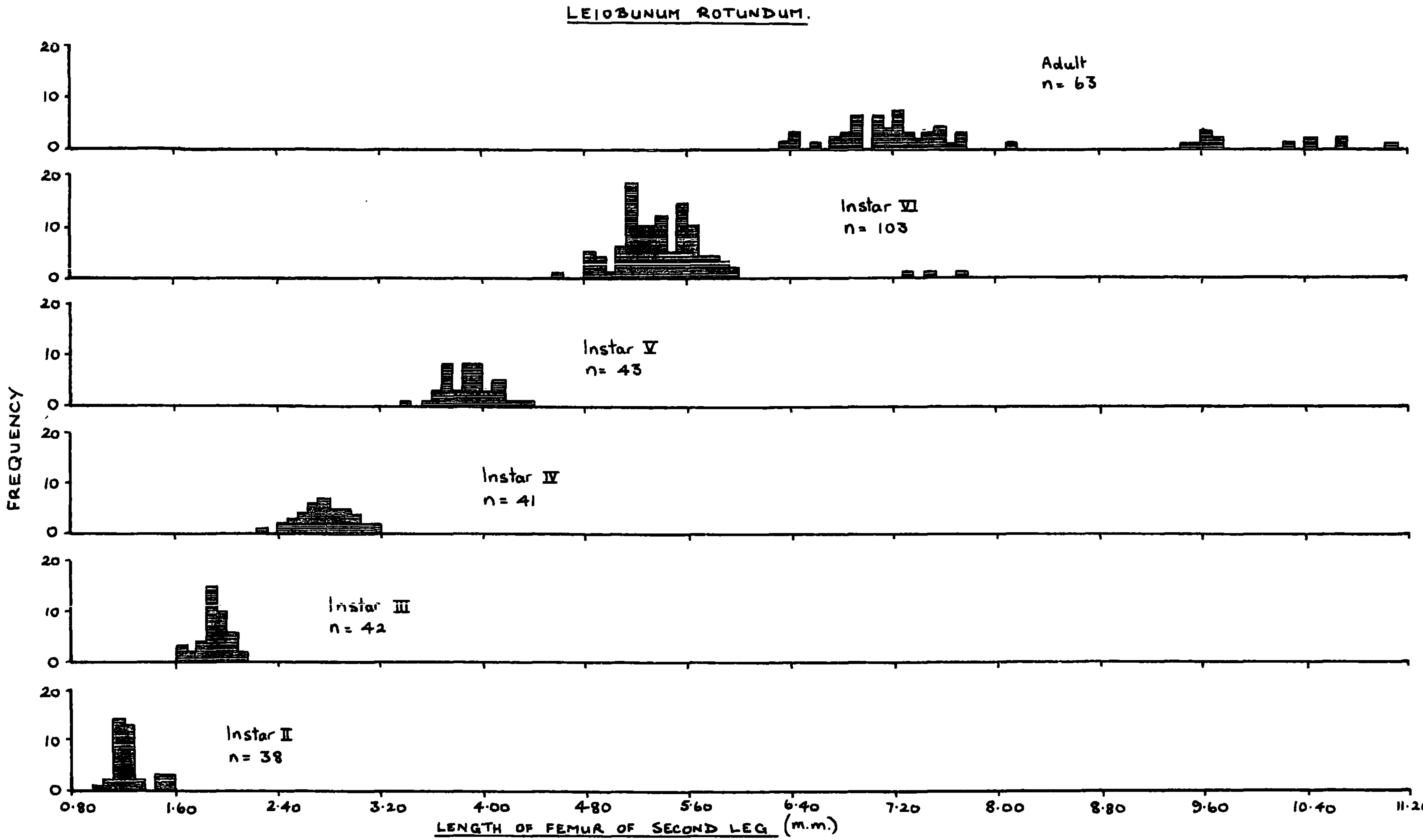


Fig. 3 Frequency distributions of second femur length of <u>Leiobunum rotundum</u>.

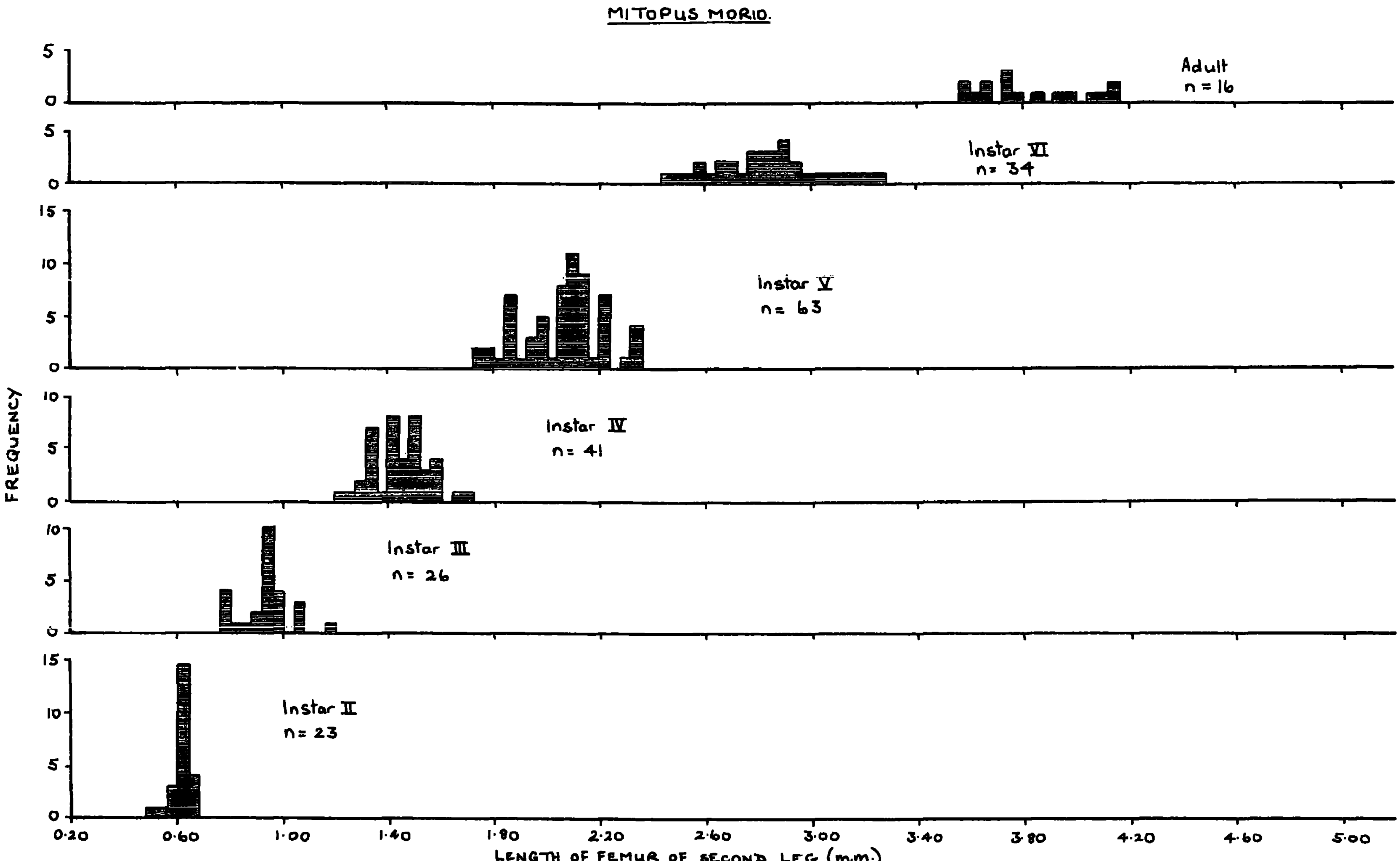


Fig. 4 Frequency distributions of second femur length of Mitopus Morio.

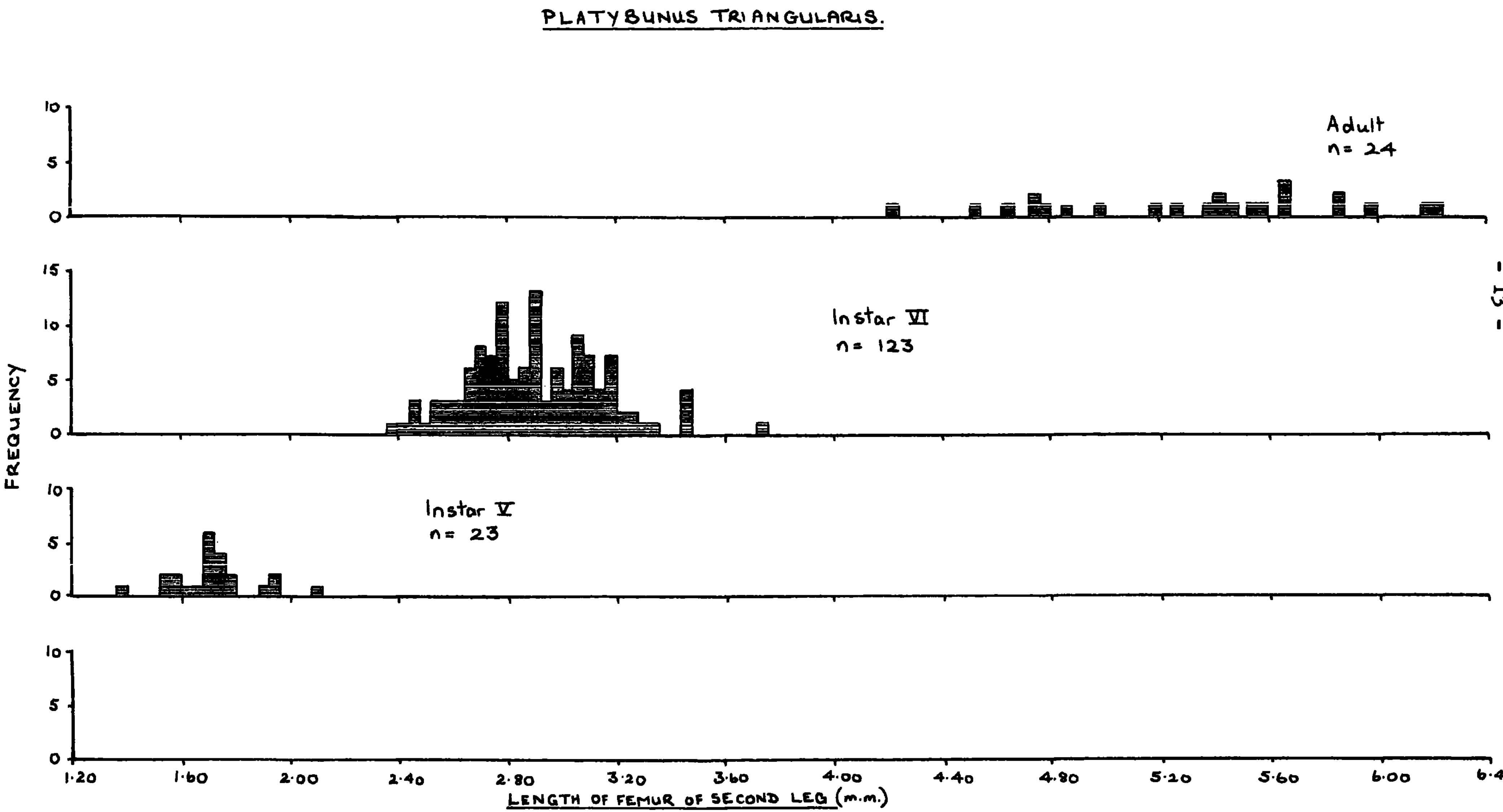


Fig. 5 Frequency distributions of second femur length of <u>Platybunus triangularis</u>.

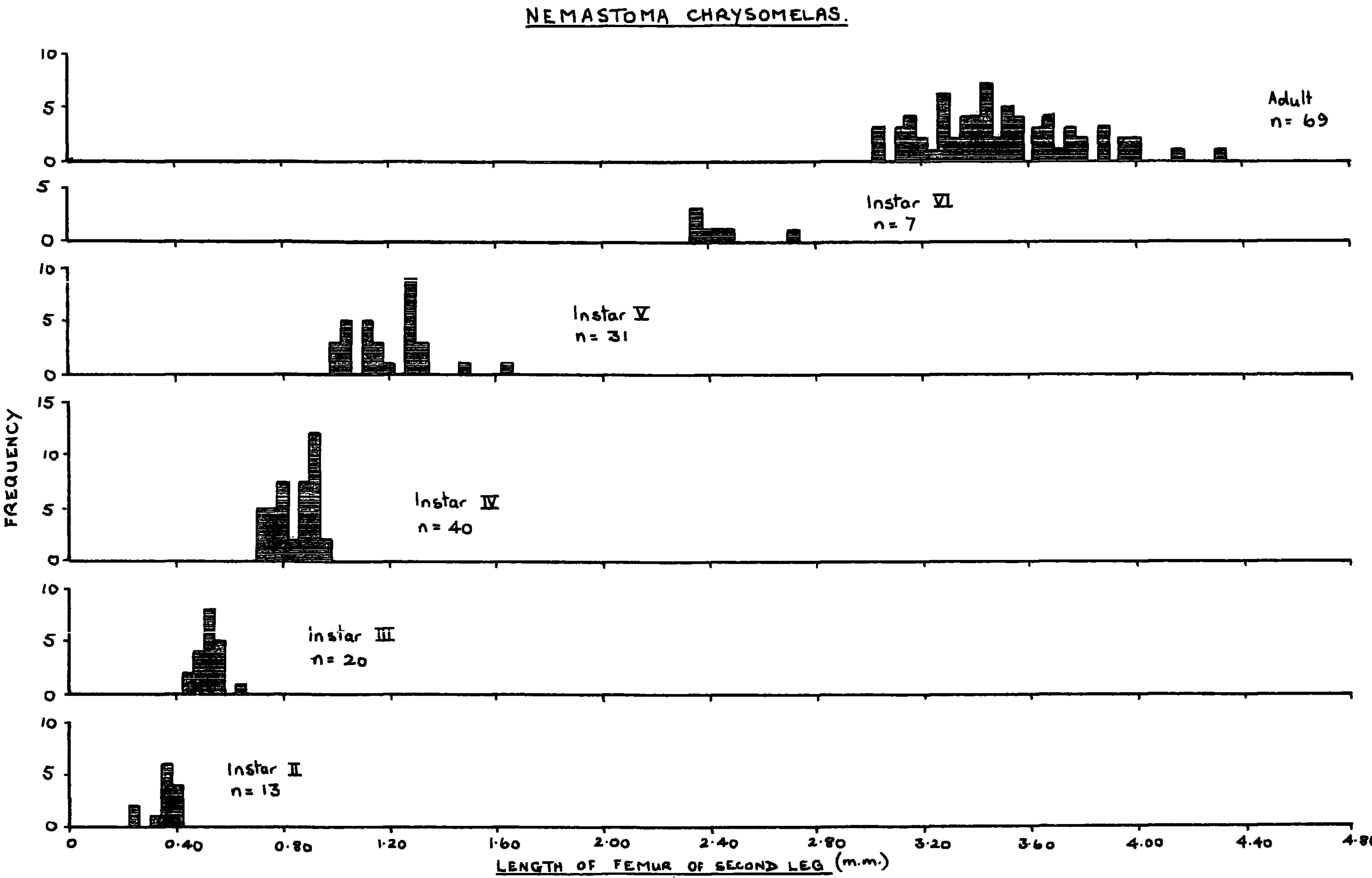


Fig. 6 Frequency distributions of second femur length of <u>Nemastoma chrysomelas</u>.

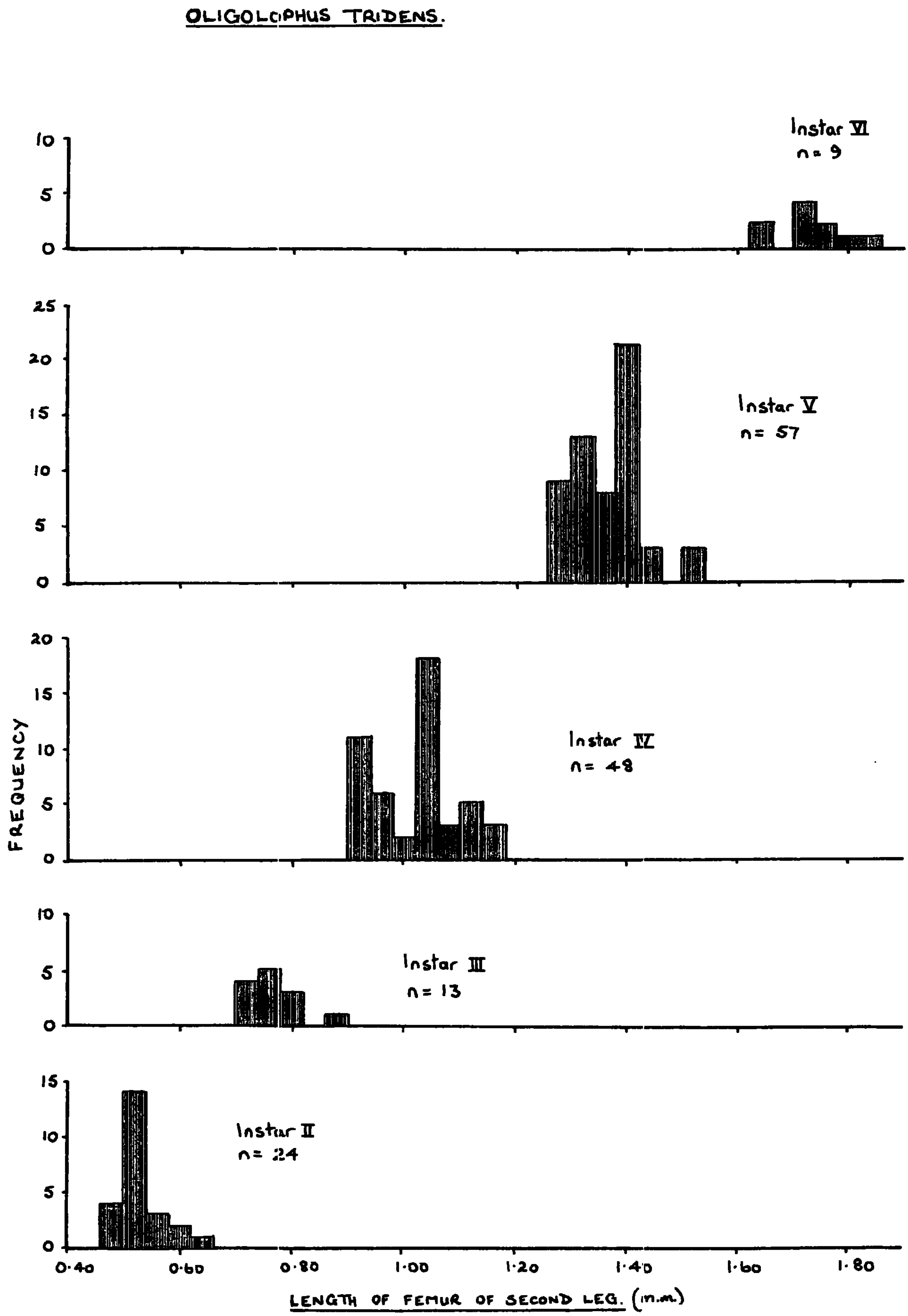


Fig. 7 Frequency distributions of second femur length of <u>Oligolophus tridens</u>.

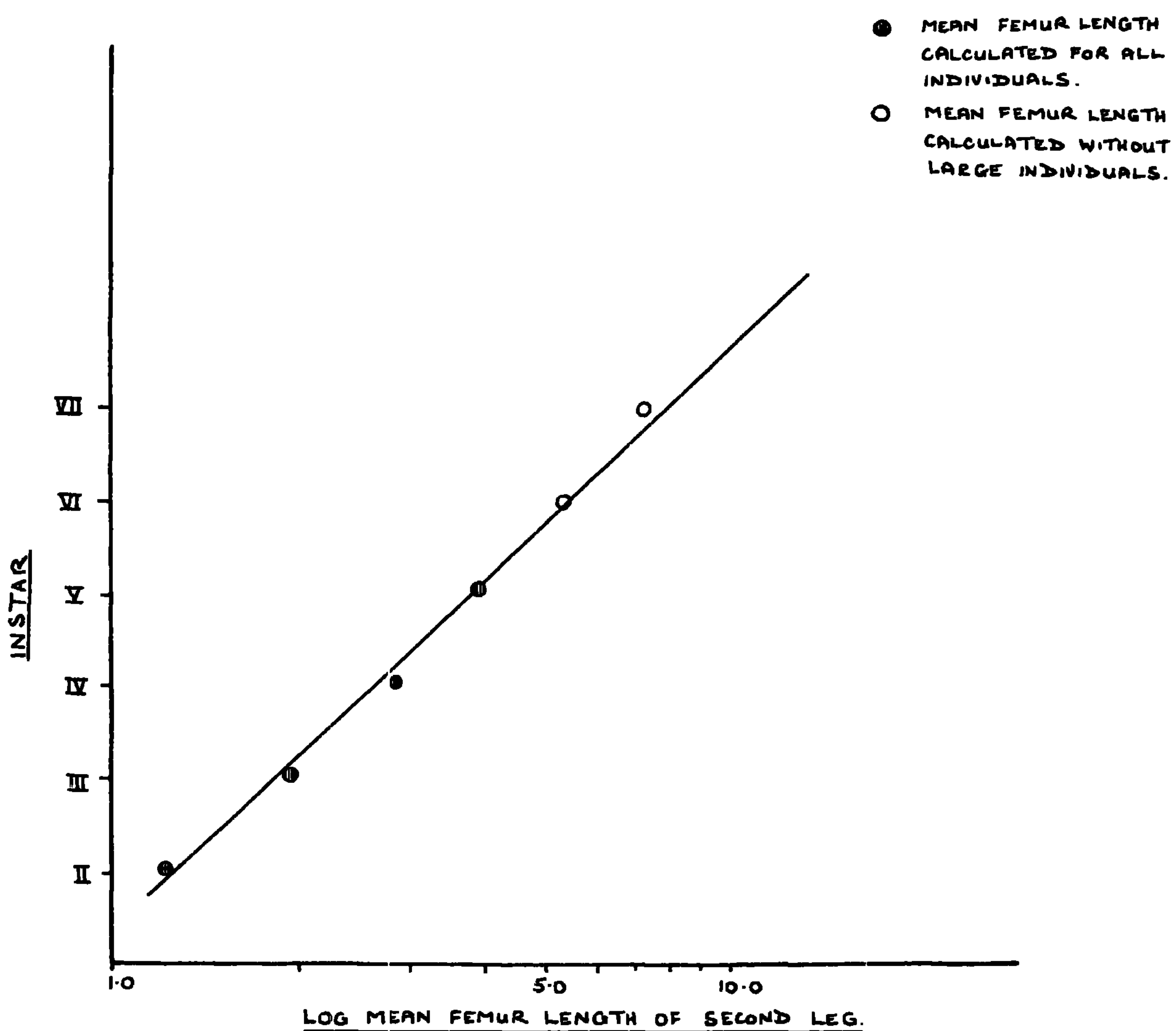


Fig. 8 Mean second femur length per instar for Leiobunum rotundum. The line through the points was drawn by inspection.

	Instar II	III	IV	V	VI	Adult
Lacinius ephippiatus	0.46 - 0.65	0.66 - 0.98	0.99 - 1.34	1.35 - 1.77	1.78 - 2.31	2.29 -
Leiobunum rotundum	0.84 - 1.60	1.61 - 2.30	2.31 - 3.40	3.41 - 4.50	4.51 - 7.76	6.20 -
Mitopus morio	0.49 - 0.77	0.78 - 1.20	1.21 - 1.71	1.72 - 2.41	2.42 - 3.27	3.28 -
Platybunus triangularis				- 2.20	2.21 - 4.06	4.07 -
Nemastoma chrysomelas	0.23 - 0.44	0.45 - 0.65	0.66 - 0.98	0.99 - 1.90	1.91 - 2.90	2.91 -
Oligolophus tridens	0.47 - 0.67	0.68 - 0.90	0.91 - 1.23	1.24 - 1.63	1.64 - 2.12	2.13

Table 2. Determination of instars by femur length of the second walking leg (length in m.m.).

No figures are available for instars II, III, IV of Platybunus triangularis. The figures in red for Oligolophus tridens are those of Heightons.

It was apparent from this that the three immature specimens ranging from 7.28 mm - 7.76 mm in instar VI had probably moulted into a seventh immature instar. It therefore seems possible that Leiobunum rotundum occasionally passes through eight instars before reaching adulthood, and this would be supported by the information collected for the very large specimens with femur lengths above 9.40 mm. which would be the eighth and adult form. It is necessary for more data to be reviewed here to verify this suggestion. For the purpose of this study they have been included in the instars for which they appear in Fig. 3.

Generally the results of Heighton agree with those species which are common to this study. It is in the adults that the major discrepencies occur and this is due to his larger sample. In Oligolophus tridens, it was necessary to use his figures from the sixth instar onwards due to the late appearance of this species towards the end of the study; and thus the provision of insufficient data to compile a reliable histogram.

The upper and lower limits of each instar of the six species are shown in Table 2. These were originally arrived at by producing graphs, the vertical and horizontal axes of which were, accumulative frequency and length of femur of second leg (mm) respectively. These were transcribed into histograms for ease of interpretation. The figures for Platybunus triangularis show only the upper limits for instar V, for this is one of the species which mature in early summer and lays eggs from which the young hatch and spend the winter in the immature stage (Sankey 1949(a)). Thus at the start of the study this species had already reached the later instars in comparison to the remaining species which were just beginning to hatch.

IV ACTIVITY OF THE SPECIES

IV(a) Population Estimation

The results from the Berlese funnel extractions and hand sorting of the quadrat samples were used to estimate the populations of each of the individual species throughout the study. A mean value for each species was calculated for each quadrat at every sampling occasion and the population calculated as a function of this mean.

The quadrat samples were grouped into three, corresponding approximately to the monthly periods of May, June and July (see Table 1). Having calculated the population estimates and plotted these and their confidence limits for the three periods there was no indication of either a significant decrease or increase in the numbers for any species (Table 3). After synchronised hatching the number of individuals in the population must inevitably decrease as death and no further births occur, but due to the large confidence limits of the present population estimates a trend was not evident.

Thus the assumption was made that no appreciable change in the populations occurred throughout the period of study and a mean population figure for each of the six Species was produced (Table 3)

IV(b) Activity Index

The number of one species captured in unit time in a pitfall trap depends upon the two factors population density and activity of that particular species. Thus by totalling all species and instars caught each week in the traps an activity index was calculated using the following formula, (Mitchell, 1963). Activity Index $= \frac{C}{D}$ where C = Numbers caught in traps, and D = Population Density. For each of the periods 1 - 3, a mean instar was calculated for the six species. These were arrived at from both the population samples and the pitfall data and appear in Table 4. Although the results from each source are similar, mean instars derived from the quadrat samples were

	PERIOD 1	PERIOD 2	PERIOD 3	MEAN POPULATION
Lacinius ephippiatus	4096 ± 13312	1024±716	2560 ± 921	2560 ± 620
Leiobunum rotundum	1024 ± 998	-	1024 ± 716	1024 ± 600
Mitopus morio	2560 ± 1229	512±502	3072 ± 1024	2048 ± 581
Platybunus triangularis	-	1024±716	1024 ± 716	1024 ± 485
Nemastoma chrysomelas	10240± 3070	13824±3277	10752 ± 3584	11605 ± 598
Oligolophus tridens	512 ± 502	4096±1434	3584 ± 1536	2730 ± 778
TOTAL	18432	20480	22016	20991

Table 3. Population estimates for each of the six species in the study area (640 sq. metres). Periods 1,2,3, refer approximately to May, June, July 1970 respectively (see Table 1). The confidence limits are expressed to one standard error.

SPECIES	SOURCE OF Estimation	PERIOD 1 MEAN	PERIOD 1 SE	PERIOD 2 MEAN	PERIOD 2 SE	PERIOD 3 MEAN	PERIOD 3 SE
Lacinius ephippiatus	Berlese Funnel Extraction	2.87	0.27	4.50	0.35	7.0	-
	Pitfall Collections	2.92	0.06	5.43	0.03	6.96	0.05
Leiobunum rotundum	Berlese Funnel Extraction	3.00	0.71	-	-	5.00	0.71
	Pitfall Collections	2.40	0.08	4.71	0.09	6.35	0.02
Mitopus morio	Berlese Funnel Extraction	2.80	0.34	5.00	-	5.83	0.15
	Pitfall Collections	2.61	0.03	4.78	0.07	6.30	0.14
Platybunus triangularis	Berlese Funnel Extraction	-	-	7	-	7	-
	Pitfall Collections	5.82	0.04	6.51	0.08	6.75	0.22
Nemastoma chrysomelas	Berlese Funnel Extraction	2.41	0.15	3.96	0.11	4.95	0.06
	Pitfall Collections	3.91	0.35	5.91	0.22	6.27	0.14
Oligolophus tridens	Berlese Funnel Extraction	2.0	-	2.37	0.17	3.85	0.24
	Pitfall Collections	-	-	2.22	0.08	4.25	0.09

Table 4. Comparison of the mean instars of the six study species from different sources throughout Periods 1,2,3 (see Table 1).

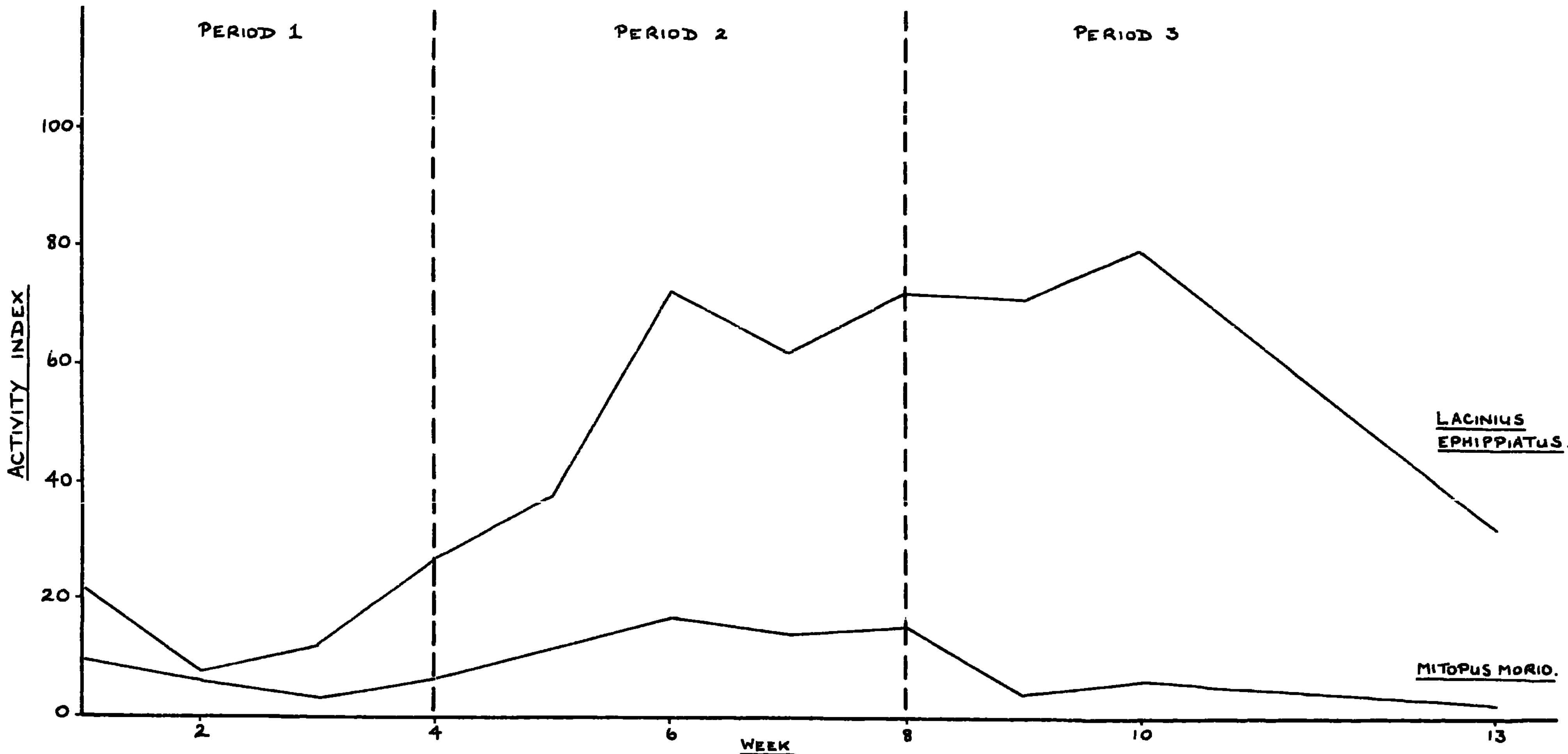


Fig. 9 Activity Index against week for Lacinius ephippiatus and Mitopus morio. Periods 1,2,3, correspond approximately to the months May, June, July respectively (see Table 1).

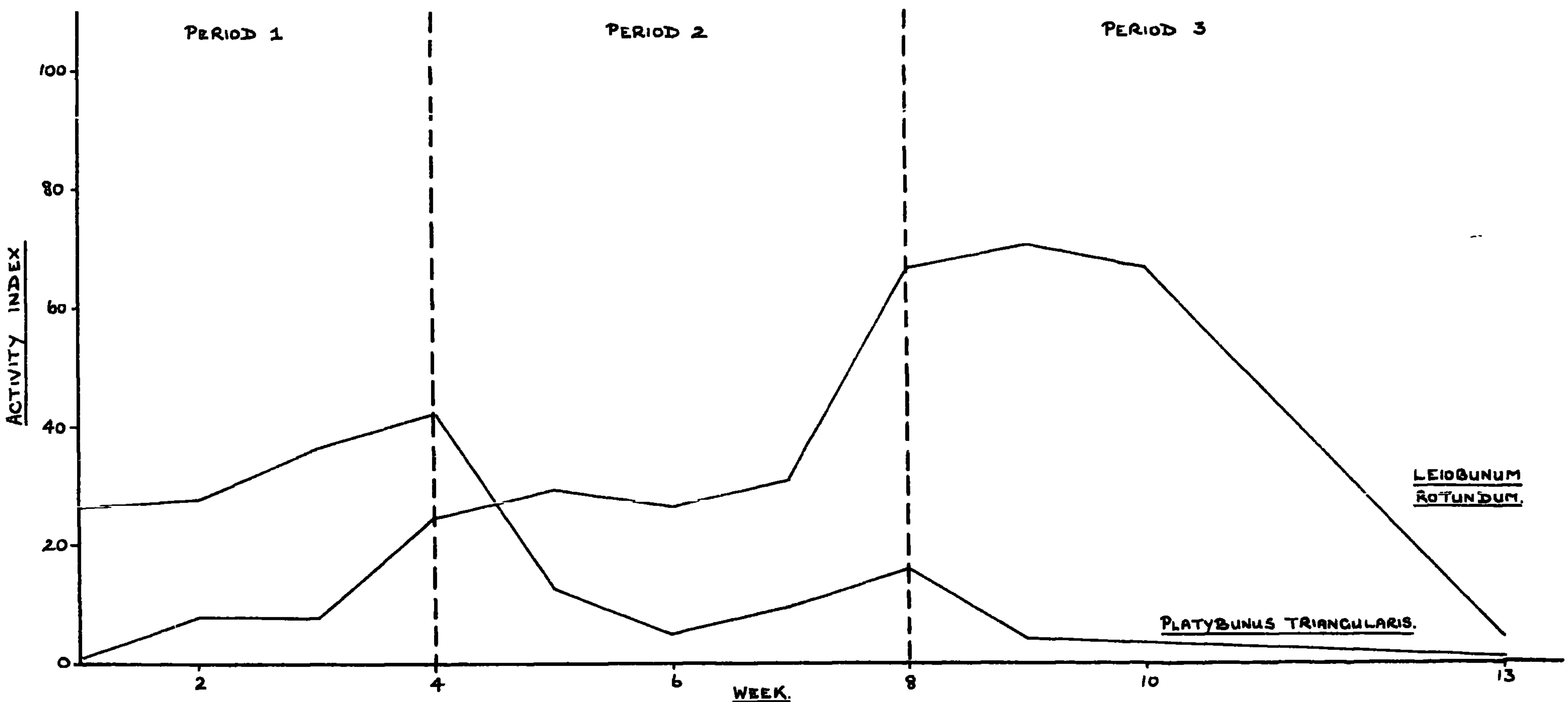


Fig. 10 Activity Index against week for Leiobunum rotundum and Platybunus triangularis. Periods 1, 2, 3 correspond approximately to the months May, June, July respectively (see Table 1).

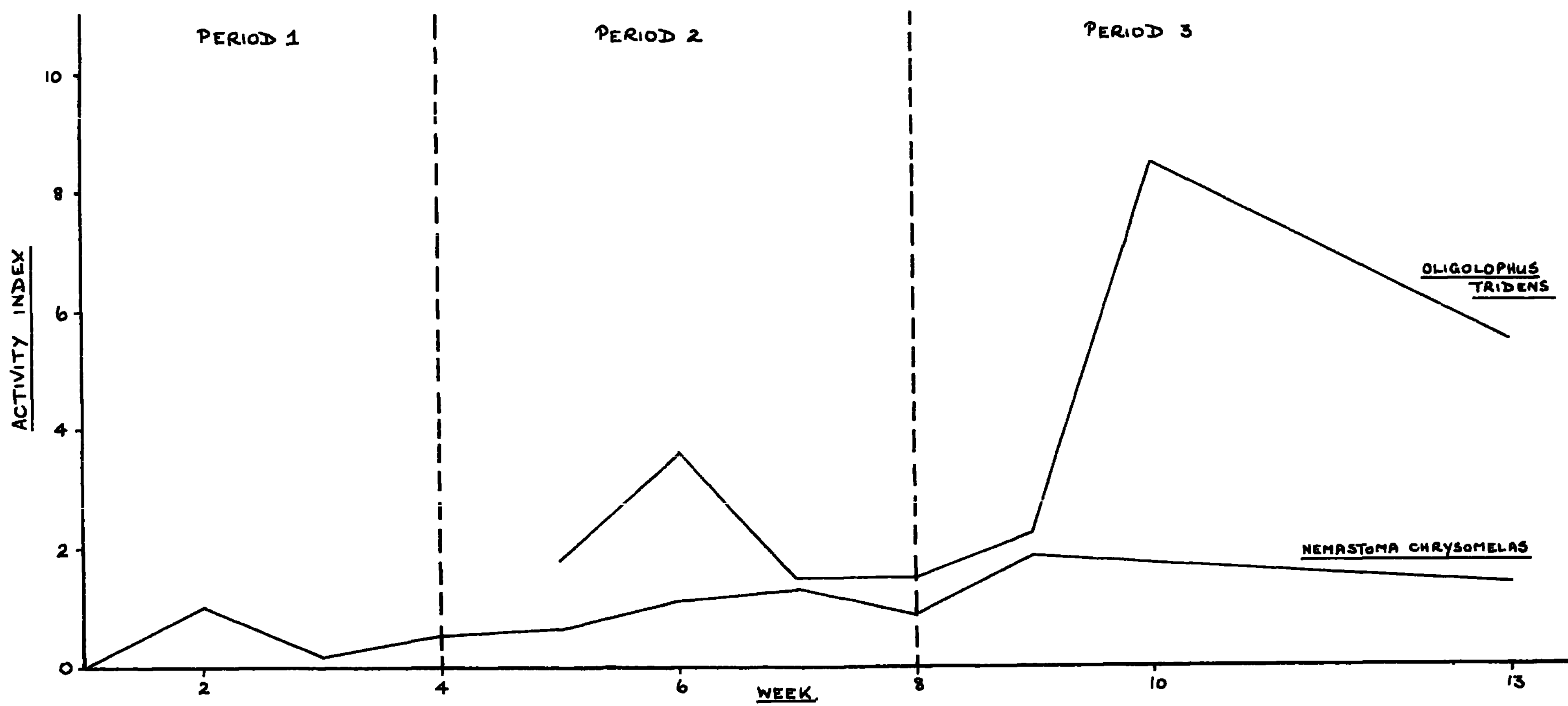


Fig. 11 Activity Index against week for Oligolophus tridens, and Nemastoma chrysomelas. N.B. Scale increased x 10 in comparison to Figs 9,10. Period 1,2,3, correspond approximately to the months May, June, July respectively. (see Table 1).

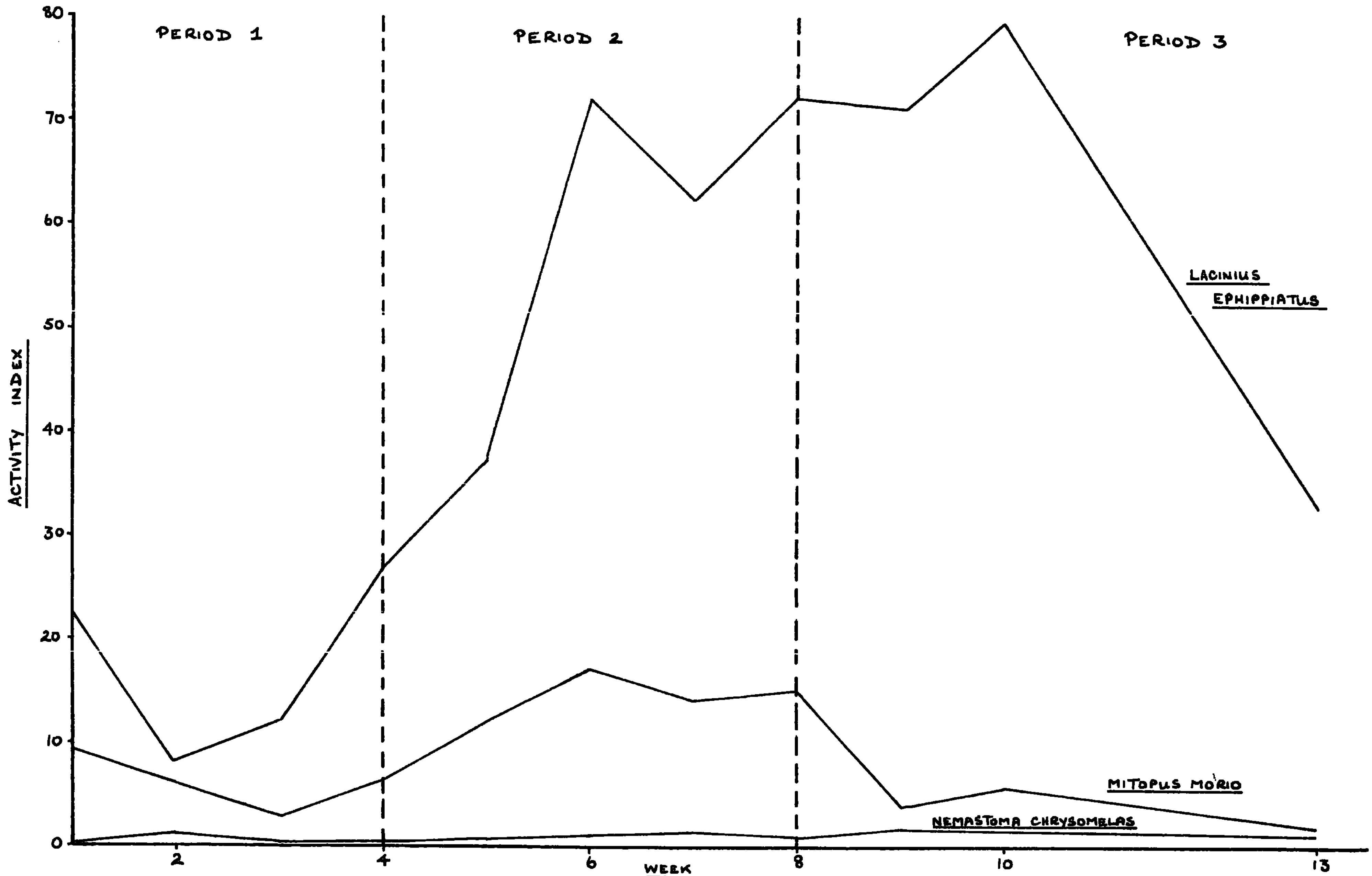


Fig. 12 Activity Index against week to show comparison between Lacinius ephippiatus, Mitopus morio, Nemastoma chrysomelas. Periods 1,2,3 correspond approximately to the months May, June, July respectively (see Table 1).

SPECIES	PERIOD 1 Mean Activity Index	PERIOD 1 Mean Instar	PERIOD 2 Mean Activity Index	PERIOD 2 Mean Instar	PERIOD 3 Mean Activity Index	PERIOD 3 Mean Instar	OVERALL MEAN ACTIVITY INDEX
Lacinius ephippiatus	17.4	2.9	61.1	5.0	61.2	7.0	45.2
Leiobunum rotundum	10.2	2.8	38.1	4.7	46.9	5.7	30.3
Mitopus morio	6.2	2.7	14.7	4.9	3.9	6.0	8.6
Platybunus triangularis	32.9	5.8	10.8	6.8	2.3	6.9	16.5
Nemastoma chrysomelas	0.5	3.1	0.9	5.0	1.6	5.6	1.0
Oligolophus tridens	-	-	2.1	2.3	5.4	4.0	3.5

Table 5. Mean activity index and Mean Instar for Periods 1,2,3 (see Table 1) and Overall mean activity index for the six study species.

generally lower than those calculated from pitfall collections. This is understandable as quadrat samples were taken at the beginning of each fortnightly period in the month (see Table 1), while pitfall traps were emptied weekly and thus the traps could easily have contained instars of a later stage at the end of the month, and this would account for the higher mean value.

The mean instar values from pitfall collections for Nemastoma chrysomelas are all much higher than the quadrat sample figures. This species may be found in the adult state at all time of the year (Savory, 1945), and this suggests that the pitfall traps may be biased towards the larger individuals.

It can be seen from Figures 9,10,11, that the indices of activity suggest not only a variation from species to species but also a variation during the life history. This is particularly evident in Lacinius ephippiatus when in Period 1 (Fig 9), and when the mean instar was three (Table 4), the mean activity index was 17.4 (Table 5) less than one third of its adult value of 61.2. A similar pattern is evident in Leiobunum rotundum when in Period 1 the mean activity index was 10.2, in Period 2 was 38.1, and reached 46.9 in the last period. Platybunus triangularis however showed a reverse trend from 32.9 in Period 1 to 2.3 in Period 3. This could be due to the fact that P. triangularis is one of the species which matures in the early summer (Todd, 1949), and that this pattern of activity was the final stage in its life history which had not yet been reached by the other species at the end of the study. It is possible that the low value of activity index for M. morio in the last period was also due to the start of this stage. The mean activity index for N. chrysomelas is extremely low and in Period 1 is under one-thirtieth the value for that of Lacinius ephippiatus, a similar separation of values is found in Period 3 between the two species. Oligolophus tridens did not appear in the pitfall traps until the second period and although of low mean activity value (2.1) it increased in the last period to 5.4 when its mean instar was four.

At the end of Period 3 L.rotundum and L.ephippiatus showed a marked decrease in activity, this was also found in the other species, but with less magnitude. In no species was there an increase. During this period both the mean temperature dropped and the rainfall increased (Fig. 1), and it is likely that one or both of these contributed to this lowering of activity. L. rotundum being a member of the Leiobuninae with characteristically long legs may have been particularly impeded in this wet weather.

Fig 12 has been produced to illustrate the difference in activity index between the most active (Lacinius ephippiatus) and the least active (N.chrysomelas), with Mitopus morio acting as an intermediate example.

IV(c) Affect of trapping on population numbers

If the numbers of individuals trapped are sufficiently large in relation to the population density then unless immigration takes place the population and the catches will be severely affected. To investigate this the population densities and catches for each species were compared for the periods 1,2 and 3 and appear in Table 6. The figures from Table 6 suggest that the only species which might have been affected by trapping was Lacinius. A further test was carried out on this species by comparing catches in the outer pitfall

SPECIES		PERIOD 1	PERIOD 2	PERIOD 3	% of population captured and removed
Lacinius	Density	4096	1024	2560	50
ephippiatus	Catch	178	625	484	
Leiobunum	Density	1024	?	1024	33
rotundum	Catch	42	156	144	
Mitopus	Density	2560	512	3072	10
morio	Catch	51	120	24	
Platybunus	Density	?	1024	1024	18
triangularis	Catch	135	44	7	
Nemastoma	Density	10240	13824	10752	1
chrysomelas	Catch	21	45	57	
Oligolophus	Density	512	4096	3584	3
tridens	Catch	-	23	44	

Table 6. Population densities of study area (640 sq. metres) and pitfall catches for each of study species during Periods 1,2,3 (see Table 1).

traps with those of the inner ones throughout the periods 1,2, and 3. This assumed that if little or no immigration was taking place then the numbers caught in the inner traps would decrease with respect to the outer traps, as the latter were sampling harvestmen from the surrounding area as well as within the study area, while those within would have been catching only harvestmen from inside the area.

	OUTER	INNER	RATIO of outer to inner catches
PERIOD 1	78	97	1 : 1.24
PERIOD 2	304	321	1 : 1.06
PERIOD 3	237	247	1 : 1.04

Table 7. Number of harvestmen caught in inner and outer traps of study area in Periods 1, 2, and 3.

It can be seen that a small trend towards this decrease was found but a χ^2 test showed that there was no significant difference between the two extreme figures. Thus immigration must have been taking place to maintain population numbers. This also suggests that this species was highly active in order to replace those taken out of the population by trapping.

V DIEL STUDY

V <u>Diel Study</u>

Various mechanical devices have been used to determine the diel activity of ground living invertebrates (Williams, 1958, 1959 (a), (b)). In order to estimate the time of day that most specimens were being trapped in this study a six hourly collection was made over a number of days. The four collection times were 06.00, 12.00, 18.00 and 24.00 hrs. These studies were not made on concurrent days due to considerable variation in weather, but in all amounted to five days, two of which were wet and three dry.

Assuming that the relative proportions of catches stay the same irrespective of the weather total catches for each of the six hourly periods for the five days were compared.

	00.00-06.00hrs	06.00-12.00hrs	12.00-18.00hrs	18.00-24.00hrs	TOTAL
Specimens caught	71	11	41	112	235
% of TOTAL	30	5	17	48	100
χ^2		43.9	30.0	32.9	9.2

Table 8. Number and percentage of total of specimens caught in pitfall traps over sixhourly periods on five days.

Each of these figures show a significant difference when compared to that figure preceeding or following it ($P < .001$).

Discussion

Thus it seems that the greatest activity predominates in the hours of least light and the lowest activity in daylight hours. Heighton (1964) showed that exposure to continuous light caused considerable reduction in activity over the whole 24 hours. No diel rhythm was evident and the intensity of activity over the two periods corresponding to day and night were very similar. If the day and night periods were reversed artificially he found the rhythm was transferred to the new time but was less pronounced. Mitopus morio exhibited a fairly distinct rhythm when subjected to continuous darkness and Heighton suggests an endogenous rhythm. Other workers (Pickard - Cambridge, 1890; Todd, 1949; Sankey, 1949(b)) have pointed out that harvest spiders are mainly active at night although not strictly nocturnal. Todd (1949) showed that many harvest spiders prefer high humidities and this could account for the increased activity at night. Phillipson (1960) correlates the increase in humidity and activity at night by explaining that day flying insects shelter in herbage at this time and thus there will be an increase in prey relative to the number of harvestmen.

Comparison of Wet and Dry Days

A comparison was then made between the two wettest days and the two driest days on which the six hourly catches were made, the results appear in Table 9.

RAINFALL (INCHES)	TEMP °C MAX	TEMP °C MIN	00.00 - 06.00hr.	06.00 - 12.00hr	12.00-18.00	18.00-24	TOTAL
0.47	16	9	18	2	5	28	53
Trace	19.5	12.5	48	7	22	60	190

Table 9 Comparison of numbers of harvestmen caught in pitfall traps over six hourly periods on two wet and two dry days.

There was a significant difference between the total specimens caught on the two wet days and the two dry days. ($P < .01$).

The low catch on wet days could be due to two factors, the high rainfall and the lowering of the mean temperature. As the decrease in temperature on the wet days was only 3.5°C it was assumed that the increase in rain was largely due to the fourfold decrease in activity, although the temperature drop must have had some effect. It is suggested that the high rainfall might restrict movement particularly in the larger animals (Figs. 9,10,11) when the high surface tension of water acts upon the legs of the individuals.

VI LABORATORY EXPERIMENTS

VI Laboratory Experiments

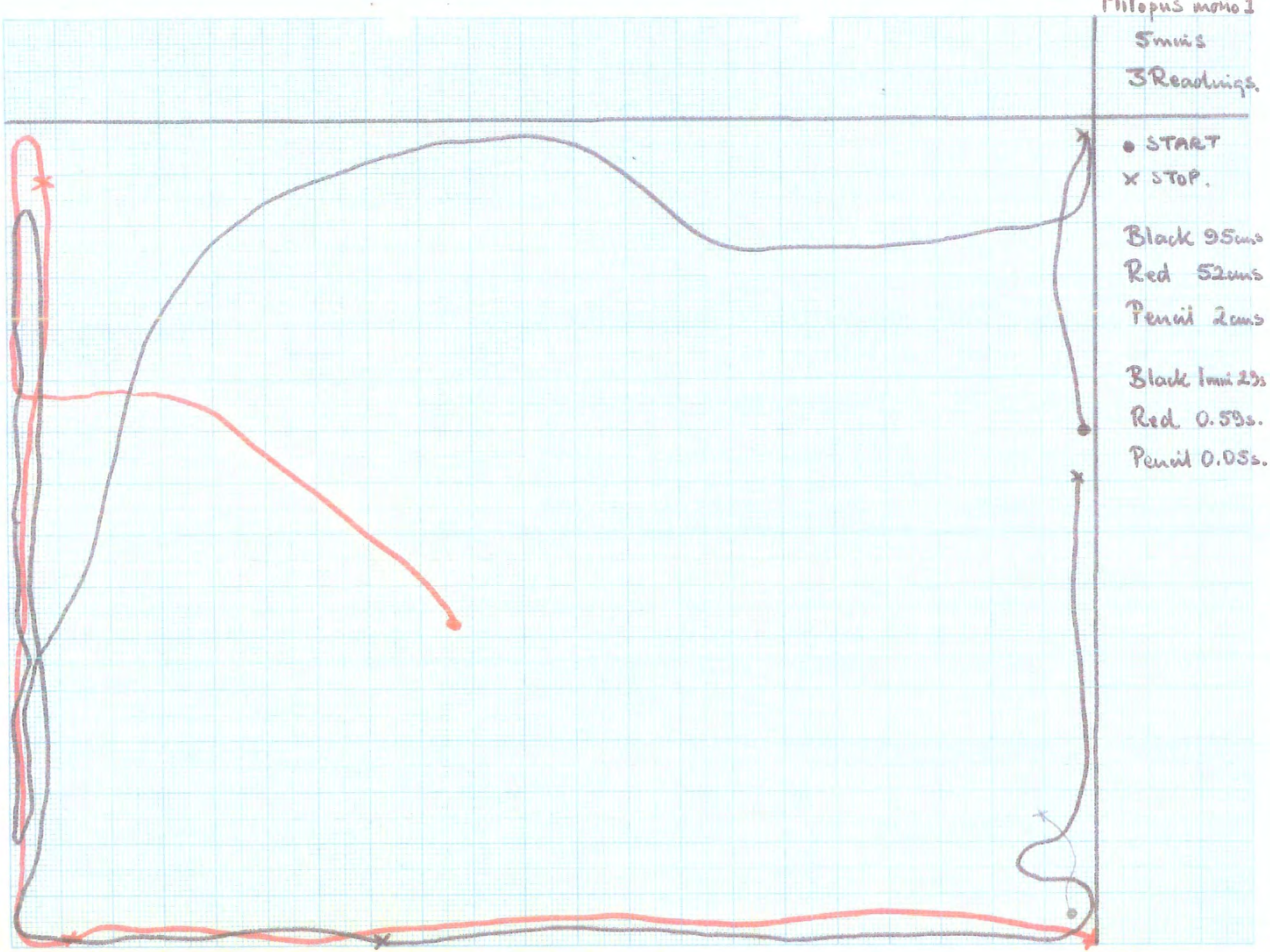
To test the activity of harvest-men in the laboratory a series of simple tests were carried out on three of the most easily obtained species, namely Lacinius ephippiatus, Leiobunum rotundum, and Mitopus morio.

The experimental animals were allowed to adjust to the laboratory conditions for at least six hours after collection. Each series of tests were performed in dim light at a time which corresponded to the time of greatest activity in the field. Five specimens of each were taken and subjected to ten 5 minute periods of observation in an enamel dish (36 x 46 cms) on the bottom of which was drawn a grid corresponding to the lines on a similarly shaped piece of graph paper. Throughout the five minute period the movement was recorded by tracing a similar path onto the graph paper. (Fig. 13) The length of time spent moving was also noted, for the distance moved was not always an indication of the activity.

By means of a rotating wheel it was possible to measure the path taken throughout the time period and to calculate a mean distance covered for each harvestman. Similarly a mean time of movement was produced for each specimen and for each species. The results are shown in Table 10.

SPECIES	MEAN TIME MOVING (SECS)	% TIME MOVING	MEAN DISTANCE COVERED (cms)
Mitopus morio	90.7 ± 27.2 (SE)	30.2	130.2
Leiobunum rotundum	80.0 ± 18.1 (SE)	26.6	125.0
Lacinius ephippiatus	77.6 ± 8.2 (SE)	25.9	131.8

Table 10 Mean time and percentage time moving, and mean distance covered in 5 minutes for three species under laboratory conditions.



Milopus morio 1
5mins
3 Readings.
● START
× STOP.
Black 95cms
Red 52cms
Pencil 2cms
Black 1min 29s
Red 0.59s.
Pencil 0.05s.

The results suggest that there is no marked difference in activity between the three species used for the laboratory experiments, this was contrary to the findings in the field where of the species used here Lacinius had the highest mean activity index (Table 5) and Mitopus the lowest. Heighton (1964) similarly found adult Mitopus to be more active than Lacinius using an aktograph. Perhaps this is an indication of the dangers of predicting the situation in the field from laboratory experiments.

VII GENERAL DISCUSSION

VII GENERAL DISCUSSION

Regular patterns of activity, both diurnal and annual are widespread in the animal Kingdom (Calhoun, 1944-46). These rhythms occur in almost all invertebrates and it was the purpose of this study to investigate the differential activity of harvestmen in the field situation.

The resultant activity indices calculated from the pitfall trap catches and the population estimates for each species showed a considerable range from the lowest, Nemastoma chrysomelas with an overall mean value of 1.0, to the highest activity index of 45.2 for Lacinius ephippiatus. This activity could have one of two functions. It might mean that the harvest-spiders are actively searching the area for food or that they are moving from one place of rest to the feeding ground and are being trapped during this transient phase. Heighton (1964) found that certain species (Mitopus morio, Oligolophus agrestis.) when they reached the penultimate and final instars, moved up from the ground layer into the trees at night possibly for the purpose of feeding. Mitopus was the only species common to this study, but was found to be one of the less active of the species in this area. In the invertebrates and particularly in the arthropods there are many examples of predatory feeders. In several of these cases the prey is obtained in a variety of ways other than just hunting for it. This is exemplified well by the spiders in their diverse feeding habits (Bristowe, 1941). Some wait patiently for their food to fly or crawl into their webs while others actively seek and stalk their victims. Similarly some caddisfly larvae of the family Philopotamidae utilise their power of spinning silk for the production of nets which serve to entangle food, and other larvae just search for prey (Alm, 1926). The larvae of the neuropterous ant-lion, Myrmeleon excavates a sand pit to trap its food and waits at the bottom for an ant or insect to roll down into its jaws (Brues, 1946).

The high and low activity in harvest-spiders might similarly mean that same species are active hunters for food while others remain sedentary and await their prey. Phillipson (1960) suggested that the Nemastomatidae and the Phalangiidae might be inactive predators after his work on Mitopus morio agreed with that of Immel (1953, 1954) on Nemastoma quadripunctatum. Their findings for these species were that they had poor vision and very little sense of smell and used their legs in the same way that a spider used its web, that is, waiting for a tactile stimulation. This would imply that the longer legged species might be the sedentary ones and the hunters the shorter legged of the two groups. This was not the case however in the present study for Leiobunum rotundum has the longest legs of the six species and yet was extremely active (Mean Activity Index 30.3). Although the results for Mitopus morio (8.6) and Nemastoma chrysomelas (1.0) agree with Phillipson in that they are both of low activity, his statement for the whole of the Family Phalangiidae does not follow when it is applied to L. ephippiatus and L. rotundum both members of this Family and of high activity. It is clear that the large variation in activity from species to species needs further investigation to see if a correlation between this and their methods of feeding exists.

The variation from species to species in activity from young instar to adult was far less pronounced, and no species, except Platybunus triangularis, increases or decreases its activity by more than a factor of four. P. triangularis however showed a decrease from

32.9 in Period 1 to 2.3 in Period 3. (Table 5), almost a fifteenfold lowering. As this species was in its fifth and sixth instar at the start of the study in the first period it could mean that the trend is indicative of its life cycle termination, and had not been reached by the other species.

Although it is accepted that harvest-spiders generally eat live prey (Bristowe, 1949), records of M.morio scraping the surface of Mercuralis perennis L. leaves and L. rotundum the surface of grass leaves have been made (Todd 1950). The prey of most arachnids is diverse as is that of the Opiliones, and in several observations (Sankey, 1949(b), Todd, 1950) harvest-spiders have been seen to devour winged insects. Phillipson (1960) suggests that the increase in numbers of insects 'grounded' at night by high humidities increases the chance encounter between harvestman and food, and could explain the greater food uptake at this time.

On investigation of the highest pitfall catches throughout the twenty-four period the figures suggested an increase in activity in the darker hours (Table 8). Of the total catch 48% was caught in the hours between 18.00 and 24.00 hours, a time when there is the advantage of relatively high temperatures, high humidity and darkness. In the following six hours when the minimum temperature of the day is usually reached (Geiger, 1966) 30% of the total was trapped. Each set of six hourly figures was significantly different to the one preceeding or following it ($P < .001$) Thus the results in this study agree with other works in their findings on this subject, but unless further research is carried out here the exact cause of this nocturnal activity increase must still be left to conjecture.

The laboratory studies on activity were comparatively simple and were intended as a support to the field investigation, but were found to be quite dissimilar. Of the three species used for this experiment Mitopus morio was by far the least active in the field (Mean Activity Value 8.6) and yet showed comparable rates of movement (Mean time moving 90.7) to Leiobunum (Mean time moving 80.0) and Lacinius (77.6). These figures were not significantly different and thus showed a similar activity level under these conditions. Several factors need to be considered here to explain the results. The most obvious feature is that of the experimental arena which impeded no movement. Mitopus has longer legs than Lacinius and this might account for its increased activity in an area devoid of obstructions, although Leiobunum, with the longest legs, spent much of its time in a stationary position, perhaps a 'carry over effect' from the field. The differences in physical conditions within the arena in comparison to the field must also have had some marked effect on the experiment. In the field the vegetation obviously obstructs different sized harvestmen to a lesser or greater extent and it must be assumed that when subjected to an open arena the differences are less apparent. Heighton (1964) found that Mitopus morio was far more active in the laboratory than Lacinius. In using an aktograph he showed that over a 24 hour period Mitopus made a mean number of 8.25 moves and Lacinius only 4.60. There needs to be more detailed study here to investigate the contrary findings of the field and laboratory activities.

It is conceivable that some species of harvestmen are more susceptible to pitfall traps while others are able to avoid them (Greenslade, 1964) and in order to validate this it would be necessary to devise a field arena and test the 'trappability' of the individual species. However it seems likely that the large difference in activity index would still override this factor and that the existence of the high and low indices is a real one. The activity indices are a function of both population estimates and numbers caught in the pitfall traps. It is evident from the variation in the population estimates that this is the most unreliable of the calculations. However with the time available for the study it was not possible to take more or larger samples. With more time the population estimates could be improved to provide a more accurate result.

Suggestions for the causes of both diurnal and annual activity patterns have been numerous. In this study the fact that they exist in harvest-spiders and are different from species to species has been shown. To satisfactorily explain the reasons for their occurrence it is clearly necessary to make an extension of this intriguing topic.

VIII SUMMARY

VIII SUMMARY

1. The differential activity of the following species was investigated : *Lacinius ephippiatus*, *Leiobunum rotundum*, *Mitopus morio*, *Platybunus triangularis*, *Nemastoma chrysomelas*, *Oligolophus tridens*.

2. It was found that there was a difference in activity between the species and between the instars of the species. *L.ephippiatus* was found to have the highest mean activity index of 45.2 and *N. chrysomelas* the lowest mean index of 1.0. *P.triangularis* showed a reverse trend of activity, but this was attributed to the fact that only the latter part of its life history was studied.

3. The daily rhythm of activity was found to agree with most other work in that a marked nocturnal increase was apparent.

4. Laboratory experiments showed that there was not a significant difference in activity between the three species *L.ephippiatus*, *L.rotundum*, *M.morio*.

5. It was suggested that in the light of previous work there might be two types of feeding behaviour associated with the high and low activity indices, an active hunter and a passive type.

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XI APPENDIX

XI APPENDIX (a)

Numbers of each instar of *Lacinius ephippiatus* caught in pitfall traps on each trapping occasion from Zoology Field Station, Durham.

Collection date	Instar II	III	IV	V	VI	VII
6.5.70	54	1				
13.5.70	7	14				
20.5.70		28	3			
27.5.70	1	20	47			
3.6.70			72	22		
10.6.70			10	169	6	
17.6.70				24	131	1
24.6.70				3	153	28
1.7.70					18	163
8.7.70					3	201
29.7.70						98

APPENDIX (b)

Numbers of each instar of Leiobunum rotundum caught in pitfall traps on each trapping occasion from Zoology Field Station, Durham.

Collection date	Instar	II	III	IV	V	VI	VII
6.5.70		1					
13.5.70		7	1				
20.5.70		8					
27.5.70		10	14	1			
3.6.70		3	23	4			
10.6.70				21	6		
17.6.70				6	18	5	
24.6.70				5	15	41	1
1.7.70				2	5	42	14
8.7.70						20	34
29.7.70							4

APPENDIX (c)

Numbers of each instar of *Mitopus morio* caught in pitfall traps on each trapping occasion from Zoology Field Station, Durham.

Collection Date	Instar	II	III	IV	V	VI	VII
6.5.70		19					
13.5.70		6	7				
20.5.70			5	1			
27.5.70		1	7	5			
3.6.70			3	21	1		
10.6.70			2	13	19	1	
17.6.70				1	25	3	
24.6.70			1		14	16	
1.7.70					1	7	
8.7.70					1	5	5
29.7.70							4

APPENDIX (d)

Numbers of each instar of Platybunus triangularis caught in pitfall traps on each trapping occasion from Zoology Field Station, Durham.

Collection date	Instar	II	III	IV	V	VI	VII
6.5.70					19	5	
13.5.70					4	22	
20.5.70						34	1
27.5.70						41	
3.6.70						13	
10.6.70						2	3
17.6.70						5	5
24.6.70						1	14
1.7.70						1	2
8.7.70							1
29.7.70							

APPENDIX (e)

Numbers of each instar of Nemastoma chrysomelas caught in pitfall traps on each trapping occasion from Zoology Field Station, Durham.

Collection date	Instar II	III	IV	V	VI	VII
6.5.70					1	
13.5.70	2	10				
20.5.70				2		
27.5.70	1		1	1		3
3.6.70		1	2		1	3
10.6.70			7			5
17.6.70			3	1	1	9
24.6.70			1			9
1.7.70			2	4	1	14
8.7.70				6		12
29.7.70			1	5		10

APPENDIX (f)

Numbers of each instar of Oligolophus tridens caught in pitfall traps on each trapping occasion from Zoology Field Station, Durham.

Collection date	Instar	II	III	IV	V	VI	VII
6.5.70							
13.5.70							
20.5.70							
27.5.70							
3.6.70		5					
10.6.70		9	1				
17.6.70		3	1				
24.6.70		1	3				
1.7.70			3	3			
8.7.70				23			
29.7.70				2	12	1	

APPENDIX (g)

Numbers of each instar of Nemastoma lugubre caught in pitfall traps on each trapping occasion from Zoology Field Station, Durham.

Collection date	Instar II	III	IV	V
6.5.70			1	8
13.5.70			1	2
20.5.70				1
27.5.70				1
3.6.70				6
10.6.70				3
17.6.70			1	5
24.6.70				4
1.7.70				2
8.7.70				6
29.7.70				8

APPENDIX (h)

Total number of each species caught each week in pitfall traps from Zoology Field Station, Durham. This includes individuals whose instar could not be determined when both second legs were missing.

Collection date	L.ephippiatus	L.rotundum	M.morio	P.triangularis	N.chrysomelas	O.tridens	N.lugubre	O.agrestis	O.palpinalis	P.opilio	L.blackwallii
6.5.70	57	1	19	27	1		9				
13.5.70	21	8	13	28	12		3				
20.5.70	31	8	6	37	2		1				
27.5.70	69	25	13	43	6		1				
3. 6.70	96	30	25	13	7	5	6	1			
10.6.70	185	27	35	5	13	10	3				1
17.6.70	159	31	29	10	15	4	6				5
24.6.70	185	68	31	16	10	4	4				2
1.7.70	182	72	8	4	21	6	2			1	1
8.7.70	204	68	12	3	20	23	6				7
29.7.70	98	4	4		16	15	8		1		7