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A STUDY OF THE ECOLOGY OF BEETLES (COLEOPTERA)
BY MEANS OF PITFALL TRAPS.

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Dissertation submitted as part of the requirements
for the degree of M.Sc. in Ecology.

A STUDY OF THE ECOLOGY OF BEETLES
BY MEANS OF FITFALL TRAPPING.

Introduction

Pitfall traps are commonly used in the study of the ecology of beetles. This method has been used successively for qualitative purposes such as period of activity, mark-release-recapture work and also for studies on life history.

The number of beetles trapped depends on (a) density of the population (b) activity of the individuals in the population. Briggs (1961), however, showed that in the Carabid, Harpalus rufipes and Feronia melonaria, the size of the population played a minor role in determining the number of beetles trapped.

It has been shown that variation in activity is correlated with temperature (Briggs 1961, Greenslade 1964, Murdoch 1966). This conclusion is also supported by laboratory observations. Mitchell (1963) in his studies on the Carabid, Bembidion lampion and Trechus quadristriatus found the forms inactive at a temperature below 48^o-50^oF (9-10^oC) and the latter inactive when the temperature fell below 42^oF (6^oC). Since temperature increases locomotor activity, Briggs concluded that it was the most important factor which determines the number of beetles trapped.

Gilbert 1956 (on four species of Calathus), Murdoch

1966 (on Agonum fuliginosum) and Van der drift, showed that locomotor activity is greatest during the breeding season and therefore a greater number is captured during this period.

It has been suggested by some investigators that activity increases after rain (Mitchell 1963), but Briggs (1961) found no such evidence in his studies on the two species Harplus rufipes and Feronia melonaria.

Two other factors have been considered which may cause variation in pitfall catches (a) Behaviour of a species. Van der drift pointed out that the diurnal Notiophilus species is capable of evading pitfall traps.

(b) Ground vegetation may hinder the movement of some Carabids and thus reducing the pitfall catches.

Gilbert (1956) found in Calathus that the adults are less active during the period of gonadial maturation than when the gonads are mature; and trapping peaks occur at the time when the population becomes fully mature.

Much criticism have been levelled against the use of pitfall traps for quantative and comparative purposes. Many Carabidae are known to be inactive for some time in the adult state and thus to reveal

this inactive population direct sampling methods should be used. When the use of pitfall traps is limited it should be combined with other methods of collecting such as Quadrate sampling, hand collecting, log sampling, extraction method etc. (Murdoch 1966).

In spite of some of the difficulties pitfall trapping is very useful for studies on life histories.

STUDY AREAS AND METHODS

Two areas about one mile from the Durham University Science Laboratories were chosen for the field work (a) Grassland (Zoological Field Station) (b) Woods (Hollinside Woods).

The Zoological Field Station slopes gently towards a small narrow stream. At the bottom of the slope there is a row of trees consisting mainly of Birch (*Betula pendula*), Beech (*Fagus sylvatica*) and Oak (*Quercus robur*) and this provides a thin litter layer in this area. The common grasses on the Zoological Field Station are Agrostis stolonifera, Agrostis tenuis, Holcus lanatus. The less common grasses were Festuca rubra, Poa pratensis, Alopecurus pratensis, Dactylis glomerata, and Arrhenatherum elatius.

Hollinside woods lie opposite the Zoological Field Station, only separated by a narrow road. Like the Field Station it slopes inwards.

The edge of the woods is covered with grass mainly Deschampsia flexuosa. Very little grass is found in the wood itself except for a few patches of Anthoxanthum odoratum and Milium effesum. The slope in the area in which traps were placed was practically bare of grass and the only vegetation present was bracken (Pteridium aquilinum), which was quite common in the woods. The common trees in the area on which the traps were placed, were Oak (Quercus robur), Beech (Fagus sylvatica), Silver birch (Betula pendula), Holly (Ilex aquifolium) Larch (Larix) and Sycamore (Acer). The trees provided a thick litter layer.

The traps used were glass jars (mouth diameter 5.3-5.5 cm.) which were sunk into the ground so that their rims were flush with the surface. The area surrounding the traps (12 cm.) was kept clear of weeds and debris. No guards were fitted on top of the traps as it was possible to visit the traps every week. The traps were examined and cleaned every week to prevent the beetles from escaping. Each trap was provided with some 70% alcohol to

prevent predation of smaller species by larger species and birds. The alcohol also served as a preservative. The beetles were placed in Pampels solution (preservative) soon after collection, as some of the specimens were later required for dissection.

Sampling on the Field Station began in November 1965. Fifty traps were placed in five rows each with ten traps, approximately three feet apart. Thirty additional traps were placed in this area in June to study the period of activity of the two common species.

Sampling in the woods began in March, 1966 and twenty traps were set out in four rows each with five traps. In each row two traps were placed in the litter area, one on the slope and two in the area covered by grass.

To study the density of the beetles soil samples were taken from the Field Station and extracted in Berlese funnels.

The females of six common species were regularly dissected to assess the state of the ovaries. These were Pterostichus madidus, Pterostichus vulgaris, Tachinis pallipes, Carabus catenulatus, Abax ater and Galathus piceus. The specimens were kept in Pampels liquid, which preserved the ovaries.

The condition of the ovaries was classified as follows:-

- Immature: when there was no enlargement of the ovarioles.
- Developing: by the enlargement of the ovarioles.
- Mature: by the presence of fully formed eggs in the ovary.
- Spent: when eggs were laid as shown by the enlargement of the oviduct.

RESULTS

A list of the beetles (Carabidae and Staphylinidae) caught on the Field Station and woods is given below. All the beetles were identified to the species level, using Joy's key.

(A) Zoological Field Station

The following table lists the species and also shows the months in which they occurred. X indicates the months in which large numbers were caught, x indicates the months in which fewer specimens were caught.

SpeciesMonth

	N	D	J	F	M	M	J	J	A
<i>Abax ater</i> (Vill.)						x	X	x	x
<i>Amara communis</i> (Pz.)				x					
<i>Amara plebeia</i> (Gyll.)				x	x				
<i>Anthobium atrocephalum</i> (Gyll.)			x	x					
<i>Anthobium unicolor</i> (Marsh.)				x					
<i>Atheta</i> spp.	x	x	x	x	x	x	x	x	x
<i>Bembidion biguttatum</i> (F.)				x	x				
<i>Bembidion guttula</i> (F.)					x				
<i>Bembidion lunulatum</i> (Geoff.)					x	x	x		
<i>Bembidion obtusum</i> (Sec.)					x	x			
<i>Calathus melanocephalus</i> (L.)		x				x	x	x	x
<i>Calathus micropterus</i> (Duft.)							x		
<i>Calathus Piceus</i> (Marsh.)						x	x	x	x
<i>Carabus catenulatus</i> (Scop.)						x	x	x	x
<i>Carabus nemoralis</i> (Mull.)								x	
<i>Carabus violaceus</i> (L.)						x	x	X	x
<i>Clivina fossor</i> (L.)						x	x		
<i>Conosoma lividium</i> (Er.)			x	x					
<i>Cychurus rostratus</i> (L.)						x	x	x	x
<i>Homalota pertyi</i> (Herr.)L	x	x	x	x	x	x			
<i>Leistus ferrugineus</i> (L.)							x	x	x
<i>Leistus rufescens</i> (F.)								x	
<i>Lesteva longo-elytra</i> (Goeze)				x	x	x			

<u>Species</u>	<u>Month</u>								
	N	D	J	F	M	M	J	J	A
<i>Loricera pilicornis</i> (F.)							x	x	
<i>Nebria brevicollis</i> (F.)						x	x	x	x
<i>Notiophilus biguttatus</i> (F.)							x	x	
<i>Notiophilus quadripunctatus</i> (Dej.)									x
<i>Omalius caesum</i> (Grav.)				x	x	x			
<i>Omalius excavatum</i> (Steph.)					x				
<i>Omalius rivulare</i> (Payk.)						x	x		
<i>Othius melanocephalus</i> (Gr.)				x	x	x	x	X	X
<i>Othius punctulatus</i> (Goeze)				x	x	x	x		
<i>Oxypoda nigrita</i> (Wat.)	x	x	X	X	X	x	x		
<i>Oxytelus tetracaratus</i> (Block.)				x	X	X	x	x	x
<i>Oxytelus rugosus</i> (Fab.)				x	X	X	x	x	
<i>Oxytelus sculpturatus</i> (Block.)					x	X	x		
<i>Patrobus septentrionis</i> (Dej.)							x	x	x
<i>Philonthus addendus</i> (Shp.)						x	x	X	x
<i>Philonthus splendidus</i> (F.)							x	x	x
<i>Pogonus luridipennis</i> (Germ.)								x	x
<i>Pterostichus diligens</i> (Sturm.)						x	x	x	
<i>Pterostichus madidus</i> (F.)	x			x	X	X	X	X	X
<i>Pterostichus niger</i> (Schall.)						x	x	x	x
<i>Pterostichus nigrita</i> (F.)					x	x	X	X	X
<i>Pterostichus strenuus</i> (Fz.)						x	x	x	x
<i>Pterostichus vulgaris</i> (L.)						x	x	x	x
<i>Staphilinus aenocephalus</i> (Deg.)						x	x		
<i>Staphilinus olens</i> (Mull.)							x		x
<i>Stenus aceris</i> (Steph.)				x	x	x			

<u>Species</u>	<u>Month</u>									
	N	D	J	F	M	M.	J	J	A	
<i>Stenus clavicornis</i>		x	x	x	x	x	x			
<i>Stenus flavipes</i> (Steph.)			x	x	x	x	x	x		
<i>Stenus impressus</i> (Germ.)					x	x				
<i>Stenus similis</i> (Herbst.)			x	x						
<i>Tachinis corticinus</i> (Grav.)	x	x	X	X	x		x	X	X	
<i>Tachinis marginellus</i> (F.)			x	X	x					
<i>Tachinis pallipes</i> (Gr.)					x	X	X	X	X	
<i>Tachinis rufipes</i> (Deg.)					x	x				
<i>Tachyporus chrysomelinus</i> (L.)			x	x	x	x				
<i>Tachyporus nitidulus</i> (F.)							x	x	x	
<i>Tachyporus obtusus</i> (L.)							x	x	x	
<i>Tachyporus scutellaris</i> (Rye)			x	x						
<i>Trechus obtusus</i> (Er.)							x	x		
<i>Trechus quadristriatus</i> (Schr.)							x			
<i>Quedius boops</i> (Grav.)									x	
<i>Quedius fuliginosus</i> (Grav.)	x	x	x	X	X	x	x	x	x	X
<i>Quedius rufipes</i> (Grav.)			x	x						
<i>Xantholinus grabratus</i> (Grav.)							x	x		
<i>Xantholinus linearis</i> (Ol.)		x	x	X	X	X	x	x	x	x
<i>Xantholinus longiventris</i> (Heer.)				x						

Seventy species were recorded from 31 genera. It should be noted that some genera were not recorded as too few were collected in the traps. The genera Atheta was not identified to the species level.

The total number of species given here is therefore an underestimate and the actual number of species could be well over eighty. The two best represented families

in this area were the Carabidae and Staphylinidae. From November 1965 to March 1966 about 70% of the catch came from the family Staphylinidae. This period was characterized by the trapping of Quedius fuliginosus, Xantholinus linearis, Tachinis corticinus, Tachinis marginalis, Homalota pertyi, Stenus clavicornis, and Atheta. The first five species appeared frequently in the traps. In November and December only three Carabids were captured. These were Pterostichus madidus, Calathus melanocephalus and a Bembidion species.

These three species appear to be survivors of the summer and autumn. No Carabids were recorded in January. From April Quedius fuliginosus, Xantholinus linearis, Tachinis corticinus, Tachinis marginalis and Homalota pertyi declined in numbers, the numbers of the latter three species fell rapidly. Tachinis corticinus appeared again in the traps in July and August.

From March onwards the percentage of Carabids rose and remained high until the end of August. Also common in the traps during this period was the family Histeridae, Micropeplinae and Curculionidae. The percentage of the family Staphylinidae remained high. Pterostichus madidus, Pterostichus nigrita, Pterostichus strenuus, Carabus violaceus and Abax ater were among the common Carabids in the traps.

The commonest species in the area is given below:-

<u>Species</u>	<u>Number trapped</u>
<i>Pterostichus madidus</i>	256
<i>Tachinis pallipes</i>	1000 +
<i>Tachinis corticinus</i>	231
<i>Xantholinus linearis</i>	331
<i>Quedius fuliginosus</i>	214
<i>Micropeplus porcatus</i>	76

(B) Hollinside Woods

The following table lists the number of species and also indicates the months in which they were caught:-

<u>Species</u>	<u>Month</u>					
	M	A	M	J	J	A
<i>Abax ater</i> (Vill.)			x	x	x	x
<i>Anchomenus assimilis</i> (Pk.)					x	x
<i>Atheta</i> spp.	x	x	x	x	x	x
<i>Calathus melanocephalus</i> (L.)					x	
<i>Calathus piceus</i> (Marsh.)			x	x	x	x
<i>Carabus catenulatus</i> (Scop.)			x	x	x	x
<i>Carabus violaceus</i> (L.)				x	x	x
<i>Clivina fossor</i> (L.)			x		x	
<i>Conosoma lividium</i> (Er.)		x				
<i>Cychurus rostratus</i> (L.)				x	x	x
<i>Leistus furrugineus</i> (L.)					x	
<i>Leistus rufescens</i> (F.)				x	x	x
<i>Loricera pilicornis</i> (F.)				x		
<i>Notiophilus biguttatus</i> (F.)					x	x

<u>Species</u>	<u>Month.</u>					
	M	A	M	J	J	A
<i>Omalius caesum</i> (Grav.)		x	x	x		
<i>Omalius excavatum</i> (Steph.)			x			
<i>Othius melanocephalus</i> (Gr.)				x	x	x
<i>Othius punctulatus</i> (Goeze)				x	x	
<i>Oxytelus tetracarinatus</i> (Block.)				x	x	x
<i>Oxytelus rugosus</i> (Fab.)				x	x	x
<i>Oxytelus sculpturatus</i> (Grav.)				x	x	x
<i>Patrobis septentrionis</i> (Dej.)					x	x
<i>Philonthus addendus</i> (Shp.)				x	x	x
<i>Philonthus splendidus</i> (F.)					x	
<i>Pterostichus medidus</i> (F.)	x	x	x	x	x	x
<i>Pterostichus niger</i> (Schall)				x	x	
<i>Pterostichus nigrita</i> (F.)				x	x	x
<i>Pterostichus strenuus</i> (Pz.)				x		
<i>Pterostichus vulgaris</i> (L.)	x	x	x	x	x	x
<i>Staphilinus olens</i> (Mull.)					x	x
<i>Stomis aeneocephalus</i>		x	x			
<i>Tachinis rufipes</i> (Dej.)				x	x	
<i>Tachinis pallipes</i> (Gr.)				x	x	x
<i>Tachyporus chrysomelinus</i> (L.)	x	x	x			
<i>Tachyporus obtusus</i> (L.)				x	x	
<i>Tachyporus scutellaris</i> (Rye)	x					
<i>Quedius molochinus</i> (Grav.)				x	x	
<i>Quedius rufipes</i> (Grav.)				x	x	

Thirty-eight species were recorded from the twenty-two genera. The genera Atheta was not determined to the species level. Like the Field Station all the genera were not recorded as too few were collected in the traps.

In this area the two best represented families were the Carabidae and Staphilinidae. From March to August about 60% of the catch came from the family Carabidae. In addition to these two families, only the Elateridae and Colydiidae contained species which were frequently collected in the traps. The genera Pterostichus was the commonest and represented about 30% of the total number of beetles caught in the five months of sampling.

The percentage of beetles caught in the litter area was high throughout the sampling period.

A list of the common species is given below:-

<u>Species</u>	<u>Number trapped</u>
Pterostichus vulgaris	459
Pterostichus madidus	331
Tachinis pallipes	150 +
Carabus catenulates	163
Calathus piceus	109

Eight of the common species in the two areas were studied in more detail: viz. Pterostichus madidus, Pterostichus vulgaris, Calathus piceus, Tachinis pallipes, Carabus catenulates, Abax ater, Xantholinus linearis and Quedius fuliginosus.

Because of the short period of study the life history account is based on adult abundance in traps and on gonad dissection. It was not possible to make any larval observations, although it plays an important

part in the study of the life history of a species.

(A) Pterostichus madidus

This species was common in the two areas sampled, i.e. Zoological Field Station (grassland)-woodlands. The pitfall catches of this species in the two areas are shown in fig. (1) and fig. (2). As shown in fig.(1) pitfall catches were low during the winter months. No specimens were recorded in December and January. From February onwards there was an increase in pitfall catches and in August 102 adults were captured.

This probably is its peak or very near it. Greenslade (1958-59) at Stillwood Field Station recorded a peak between July and August. In both areas as shown in fig.(1) and fig.(2) there was an unexpected decline in numbers in July. From this study it appears that the main period of activity is between June and August and this corresponds with the breeding period.

This species was more abundant in the woods. About 331 adults were trapped between March-August (in 20 traps) compared with 256 at the Field Station between November and August (in 50 traps).

The sex ratio in the traps for May, June, July and August is shown below:-

(A) Zoological Field Station (50 traps)

<u>Month</u>	<u>Number examined</u>	<u>Male</u>	<u>Female</u>
<u>MAY</u>			
5-13th	15	6	9
%		40	60
13-20th	15	8	7
%		53	47
20-27th	14	5	9
%		36	64
<u>JUNE</u>			
5-14th	18	7	11
%		37	63
15-30th	36	15	21
%		42	58
<u>JULY</u>			
1-10th	8	4	4
%		50	50
10-20th	14	6	8
%		43	57
20-30th	14	4	10
%		29	71
<u>AUGUST</u>			
1-7th	30	11	19
%		37	63
9-16th	47	20	27
%		37	63

<u>Month</u>	<u>Number examined</u>	<u>Male</u>	<u>Female</u>
<u>AUGUST</u>			
16-30th	35	15	20
%		43	57
TOTAL		236	

(B) Hollinside Woods

<u>Month</u>	<u>Number examined</u>	<u>Male</u>	<u>Female</u>
<u>MAY</u>			
5-13th	10	3	7
%		30	70
13-20th	18	8	10
%		44	56
20-27th	14	6	8
%		43	57
<u>JUNE</u>			
2-9th	32	10	22
%		31	69
9-17th	30	7	23
%		23	77
17-24th	15	9	6
%		60	40
24-31st	10	5	5
%		50	50
<u>JULY</u>			
1-8th	16	5	11
%		31	69

<u>Month</u>	<u>Number examined</u>	<u>Male</u>	<u>Female</u>
<u>JULY</u>			
9-15th	8	3	5
%		38	62
15-22nd	11	4	7
%		36	64
22-30th	10	4	6
%		40	60
<u>AUGUST</u>			
1-5th	7	2	5
%		29	71
5-12th	20	5	15
%		25	75
12-19th	43	16	27
%		37	63
19-26th	25	6	19
%		24	76
26-31st	38	17	21
%		45	55
TOTAL		307	

The total number of males and females captured in the traps during this period are 101 males 135 females on the Field Station, 110 males and 197 females in the wood.

The difference between the sexes collected in the two areas is not significantly different.* It is evident from the above table and from figures 11 and 12 that the percentage of females trapped was higher in all four months. The percentage of males gradually increase from May onwards and reaches its peak or very near its peak in August. In July there was a reduction in both sexes. The pattern of the histogram is very similar for the two areas.

In the woods the activity appears to be dominated by the females. Twice as many females were captured each month.

As shown in figure 18 the breeding period lies between May and August and this corresponds with the main period of activity. In August females lay their eggs and therefore one can expect them to be more active during this period than the males.

In March when the females appeared they were all immature. The percentage of immature females was high in March and April. After feeding we find that their ovaries develop and the percentage of females with developing eggs was fairly high in May and June. In June and July most of the females had mature eggs in their ovaries. Towards the end of July the percentage of spent females rise. The condition of the female ovaries is shown in figure 18.

* $\chi = 2.8$

One can assume that the numbers will decline rapidly towards the end of September and October. In November 1965 only three adults were recorded. The monthly sex ratio for the two areas is shown on fig. 11 and fig. 12a.

(B) Pterostichus vulgaris

This species was found on the Field Station and woods, but occurred more frequently in the latter. When sampling began in March (in woods) it was already fairly active. The pitfall catches of the adult is shown in figure 3.

This species has a well marked peak in June and July. Although the numbers did not decline rapidly in August one can assume that it would in September and October. On the Field Station where this species was not common no adults were recorded between November and April. The main period of activity occurs in May, June, July and August. It is evident from figure 3 and figure 19 that the main period of activity occurs during the breeding period.

In March most of the dissected females had immature ovaries. The percentage of females with developing eggs was high in May and June. The majority of the females examined in June, July and August had mature eggs. In August some females had laid eggs. One can conclude that this species

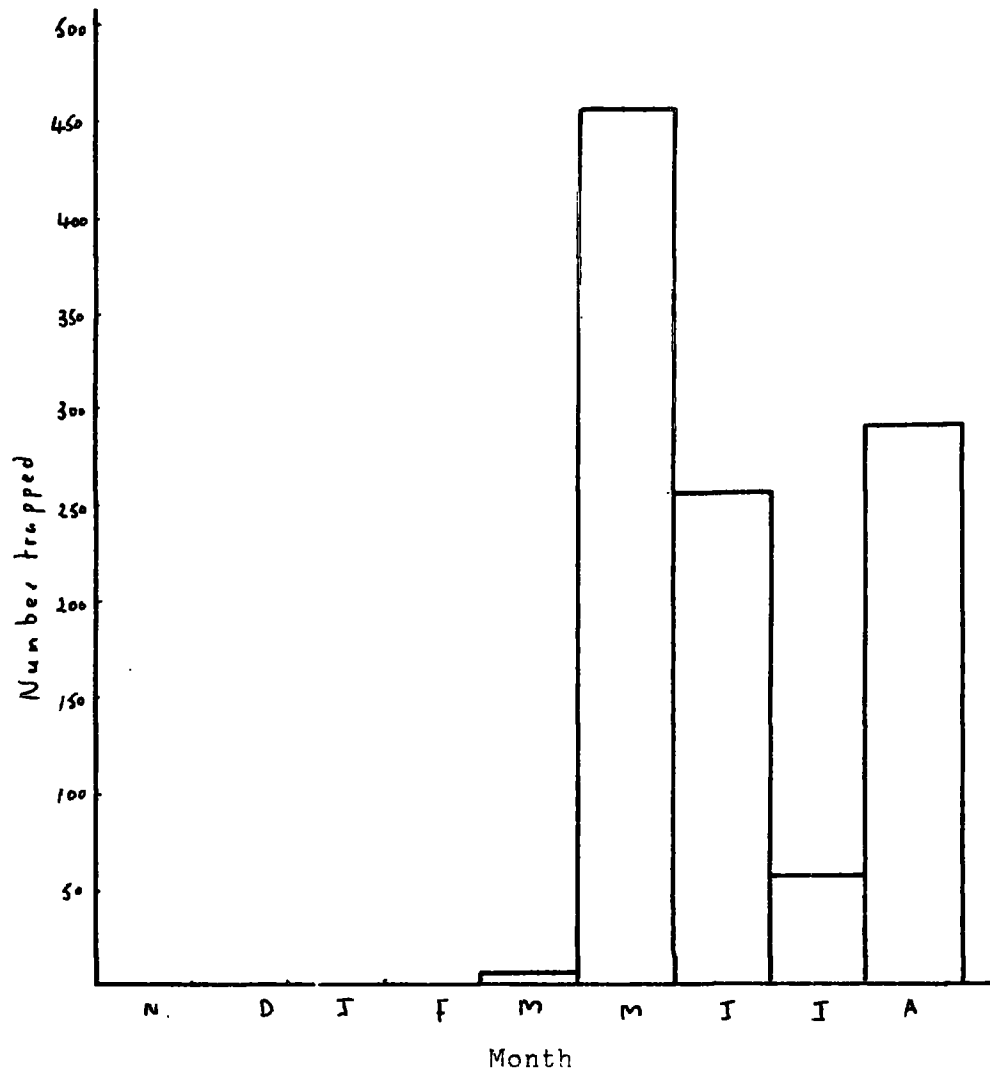


FIG 1. Monthly catches of *Pterostichus madidus* in 50 traps on the Zoological Field Station (Durham). November 1965 - August 1966.

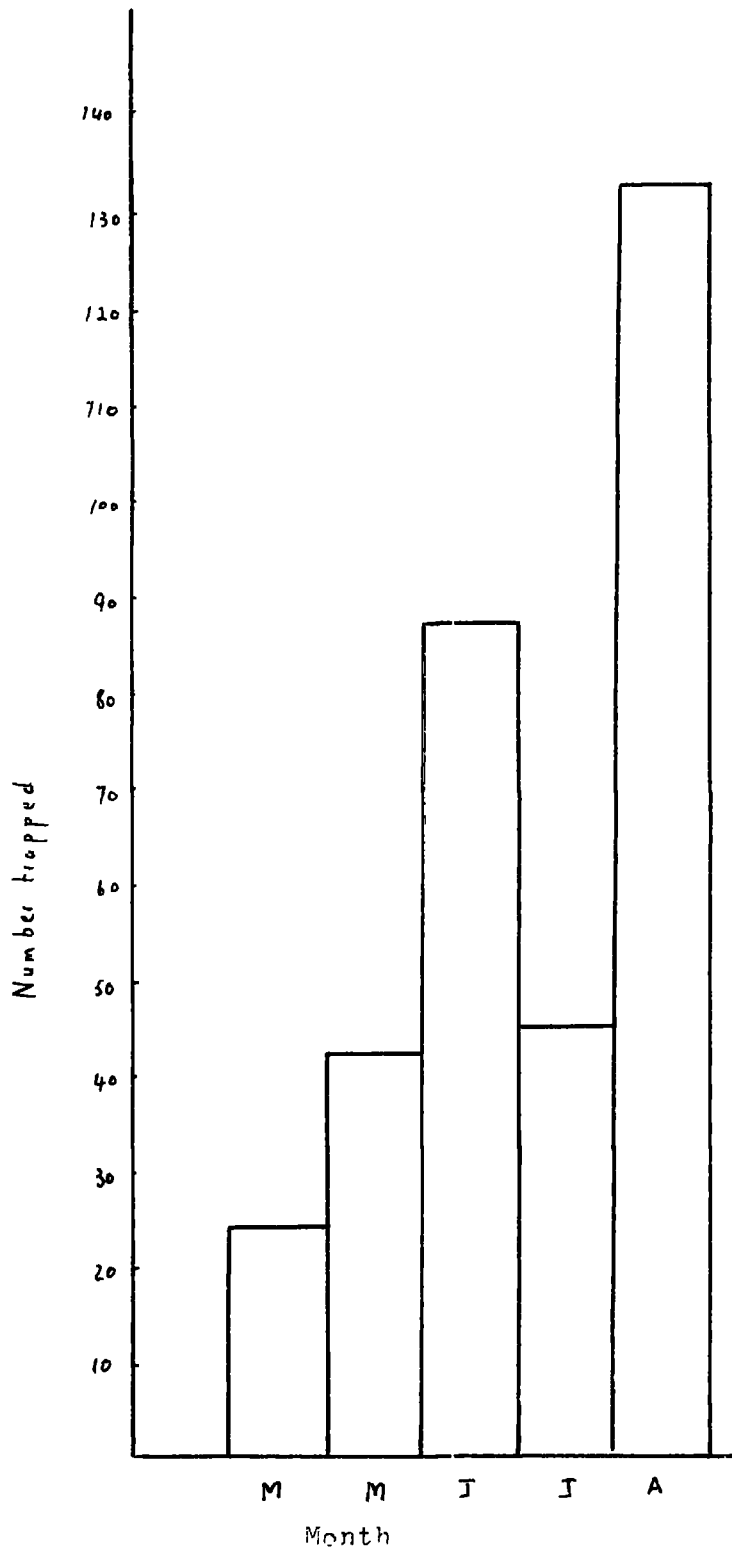


FIG 2

Monthly catches of
Pterostichus madidus in
20 traps in Hollinside
Wood, March 1966 - August 1966

appears in February, breeds in spring and lays its eggs in August and September. The percentage mortality can be expected to be high in October.

The sex ratio of this species in the 20 traps during May, June, July and August is given below:-

<u>Month</u>	<u>Number examined</u>	<u>Male</u>	<u>Female</u>
<u>MAY</u>			
5-13th	25	11	14
%		44	56
13-20th	29	16	13
%		55	45
20-27th	21	13	8
%		62	38
<u>JUNE</u>			
2-9th	26	6	20
%		23	77
10-17th	82	45	37
%		55	45
17-24th	41	23	18
%		56	44
24-31st	12	7	5
%		58	42
<u>JULY</u>			
1-9th	27	15	12
%		56	44
9-16th	51	26	25
%		51	49

<u>Month</u>	<u>Number examined</u>	<u>Male</u>	<u>Female</u>
<u>JULY</u>			
15-22nd	22	15	7
%		68	32
22-30th	10	5	5
%		50	50
<u>AUGUST</u>			
1-7th	11	2	9
%		18	82
5-12th	14	4	10
%		29	71
12-19th	10	2	8
%		20	80
19-26th	13	3	10
%		23	77
26-31st	29	10	19
%		34	66
	TOTAL	423	

In the four months of sampling 220 females and 201 males were captured in the traps. The monthly sex ratio is shown in figure 14.

In May, June and July the activity is not dominated by either sex, the percentage of females and males captured was almost the same, the percentage of males being slightly higher each month. In August the activity was clearly dominated by the females. Twice as many females were captured. As shown on figure 19 females

females begin to lay eggs in August and therefore one can expect them to be more active during this period. The condition of the female ovaries is shown on figure 19.

(C) Carabus catenulates

This species was found mainly in the woods, although it was occasionally trapped on the Field Station (grassland). The first evidence of activity occurred in May, although it has been reported that adults first appear in April. From May to July there was a gradual increase in numbers, but in August the numbers increased rapidly. In August 114 adults were captured compared with 23 in July. In May, June and July only 53 specimens were captured. One can conclude that the peak lies between August and September.

Pitfall catches of the adults are shown in figure 5. The main period of activity occurs in August and September, and this like most other Carabids corresponds with the breeding period.

The sex ratio of this species in the 20 traps during May, June, July and August is given below:-

<u>Month</u>	<u>Number examined</u>	<u>Male</u>	<u>Female</u>
<u>MAY</u>			
5-27th	11	5	6
%		45	55

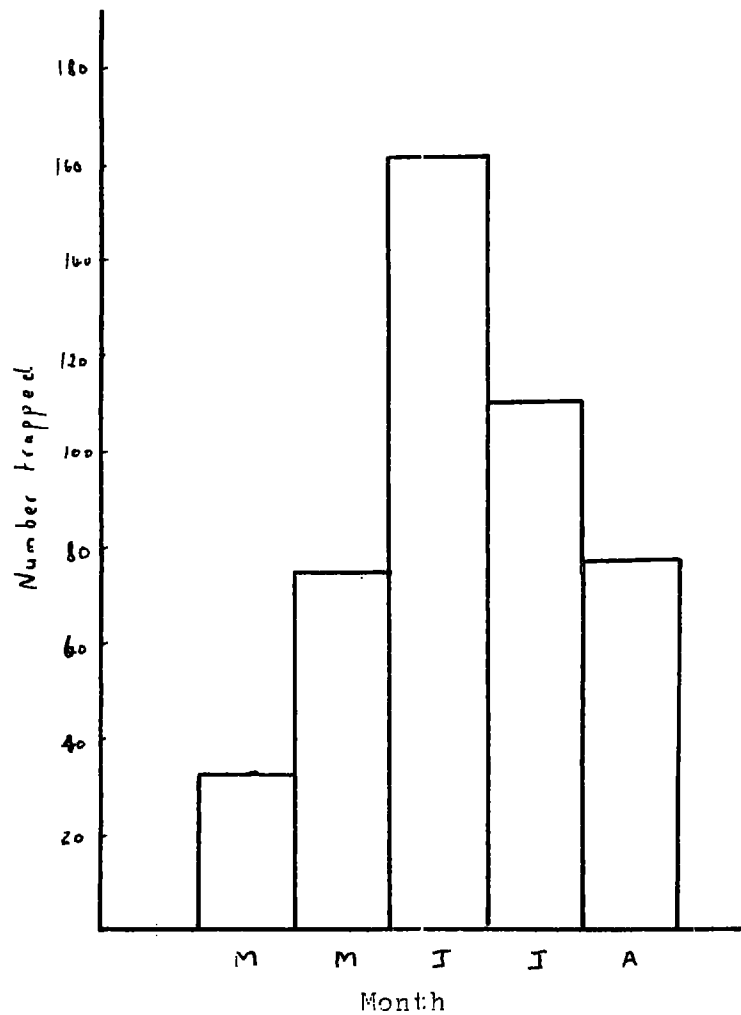


FIG 3 Monthly catches of Pterostichus vulgaris in 20 traps in Hollinside Wood, March 1966 - August 1966.

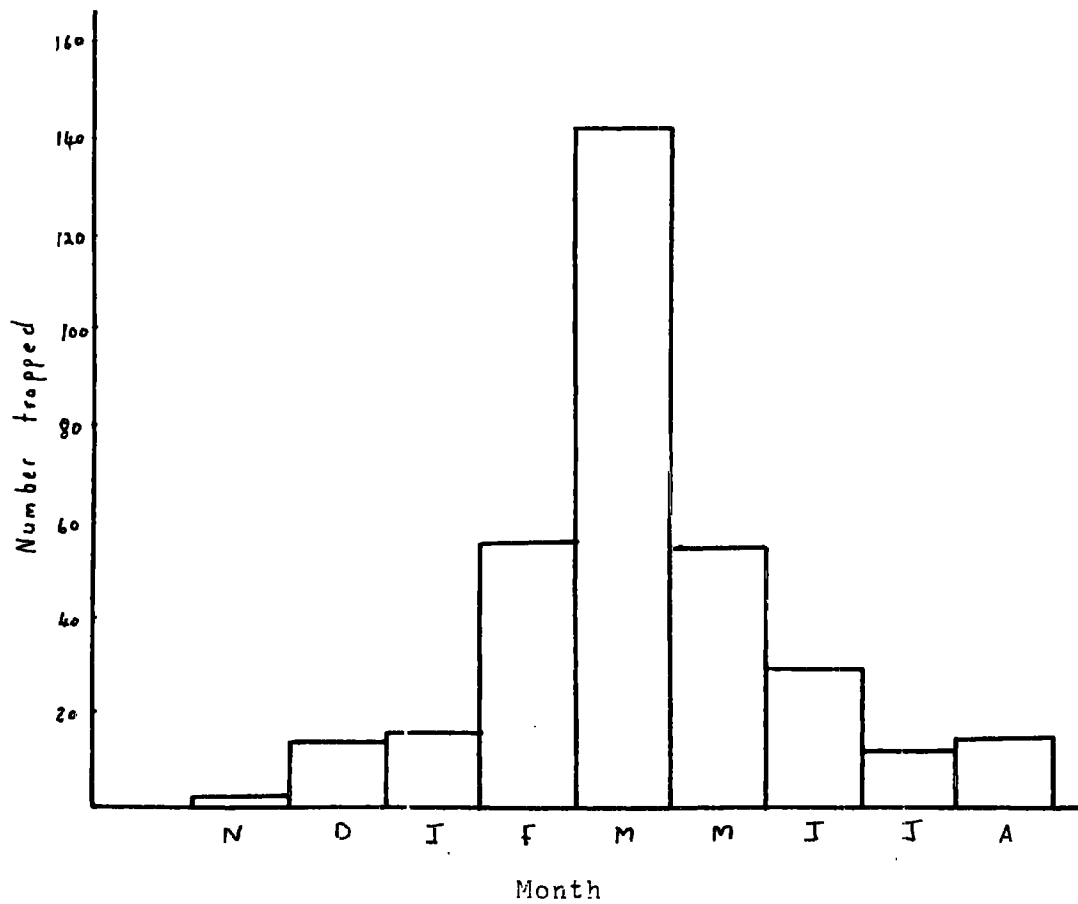


FIG 4 Monthly catches of Xantholinus linearis in 50 traps on the Zoological Field Station, November 1965 - August 1966.

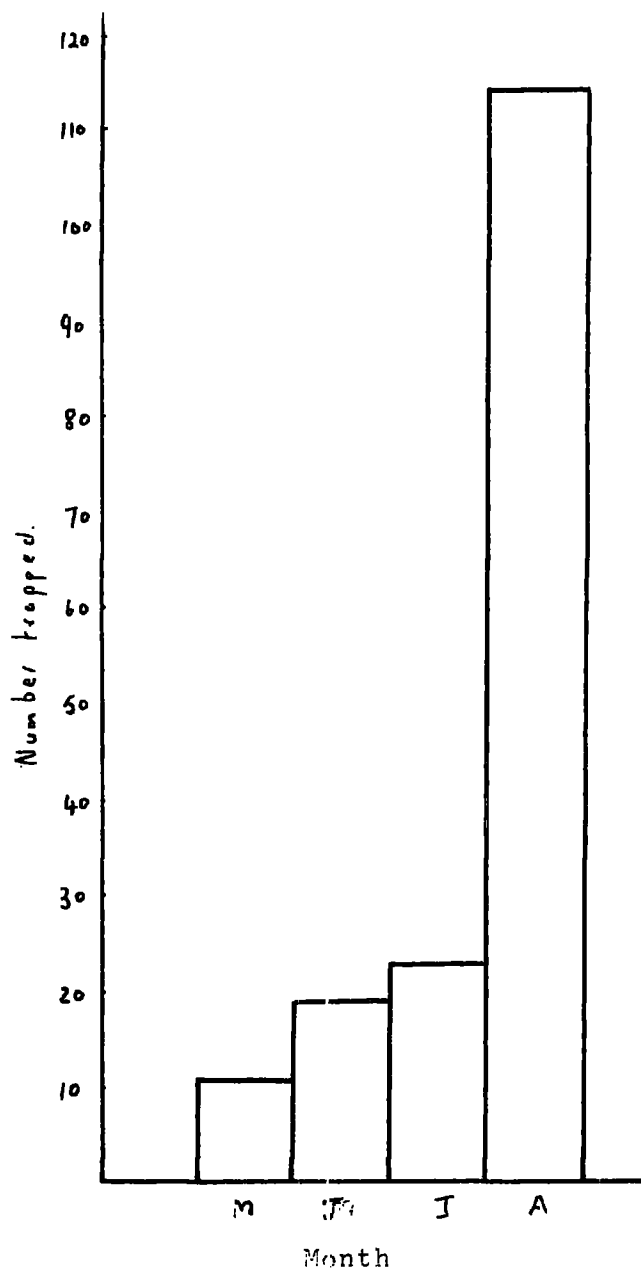


Fig 5. Monthly catches of Carabus catenulates in 20 traps in Hollinside Wood, May 1966 - August 1966.

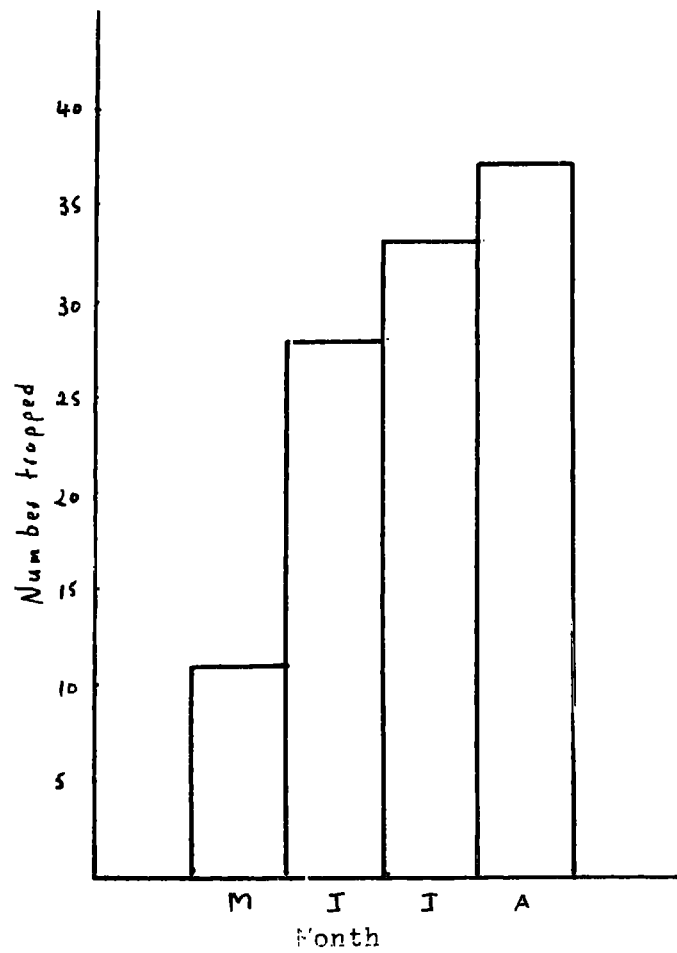


FIG 6 Monthly catches of Calathus niceus in 20 traps in Hollinside Wood, May 1966 - August 1966.

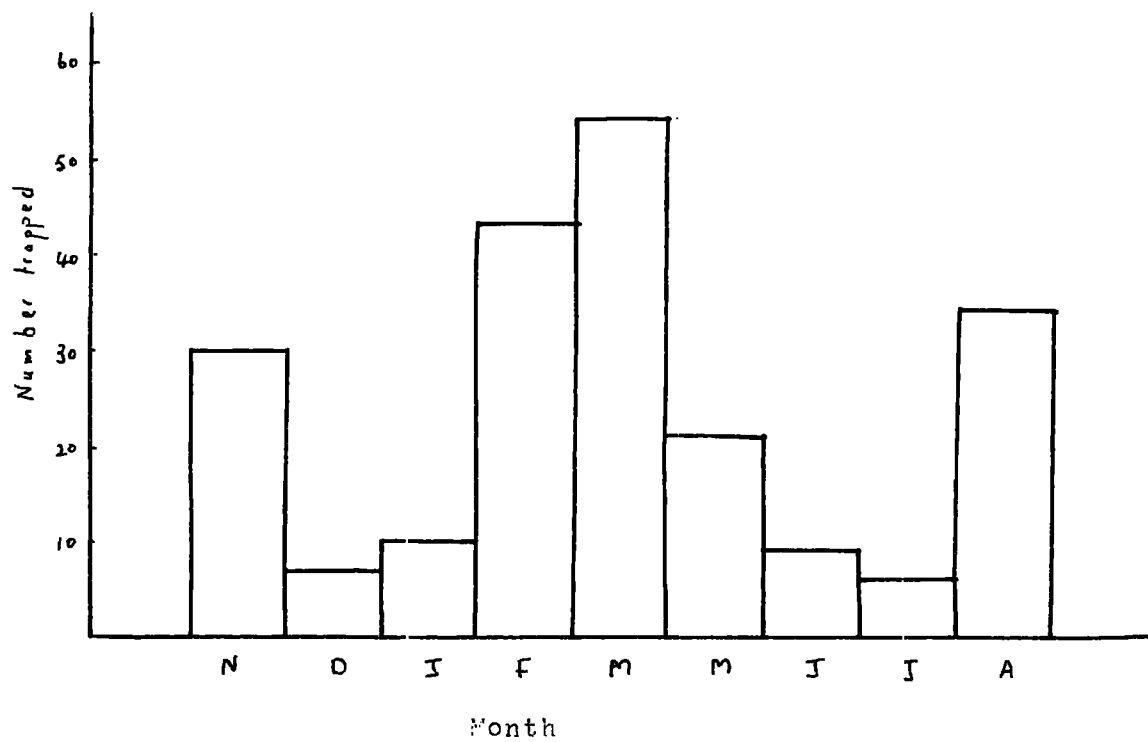


FIG 7 Monthly catches of Quedius fuliginosus in 50 traps on the Zoological Field Station, November 1965 - August 1966.

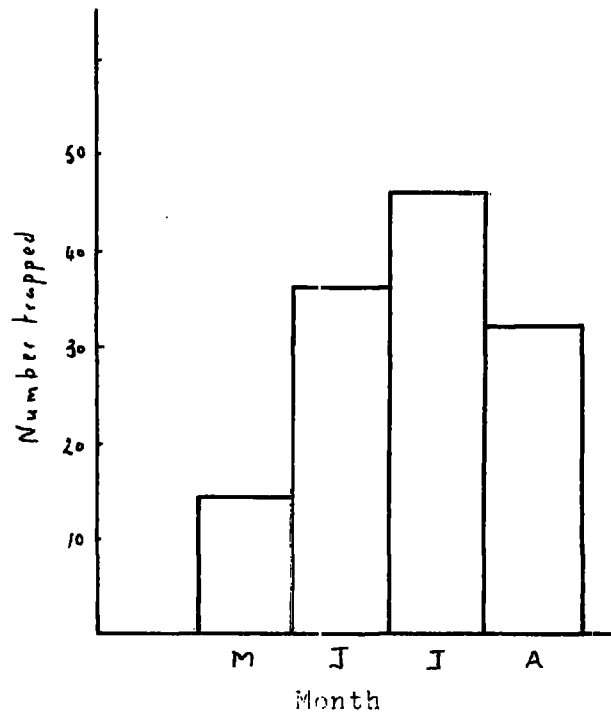


FIG 8. Monthly catches of Abax ater in 20 traps in Hollinside Wood, May 1966 - August 1966.

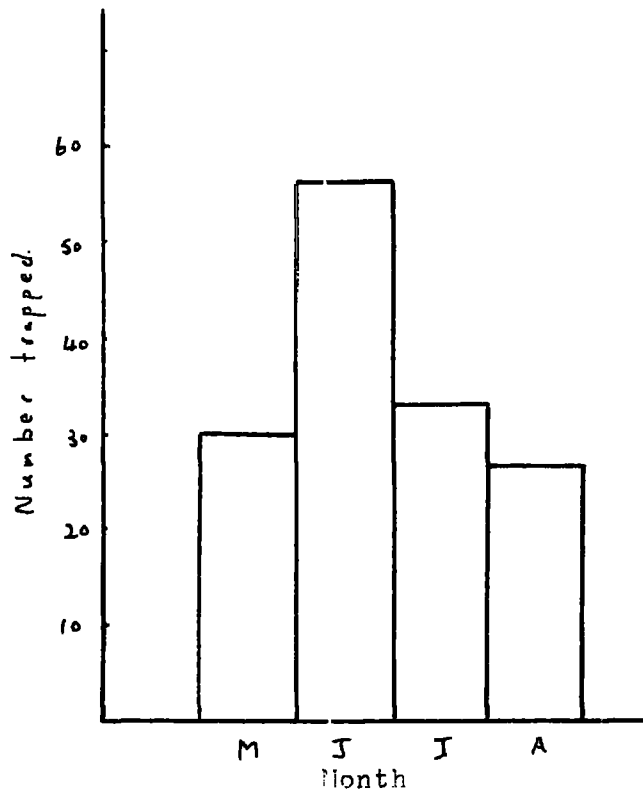


FIG 9. Monthly catches of Abax ater in 50 traps on the Zoological Field Station, May 1966 - August 1966.

<u>Month</u>	<u>Number examined</u>	<u>Male</u>	<u>Female</u>
<u>JUNE</u>			
2-9th	6	5	1
%		83	17
10-17th	6	3	3
%		50	50
17-30th	7	5	2
%		71	29
<u>JULY</u>			
1-15th	6	3	3
		50	50
15-22nd	9	3	6
%		33	67
22-30th	8	2	6
%		25	75
<u>AUGUST</u>			
1-6th	10	5	5
%		50	50
6-12th	39	24	15
%		62	38
12-19th	15	10	5
%		67	33
19-26th	16	9	7
%		56	44
26-31st	34	19	15
%		44	56
	<u> </u>		
TOTAL	<u>167</u>		

Monthly changes in sex ratio are shown in figure 15. In the four months of trapping 93 males and 72 females were captured. Unlike Pterostichus madidus the activity was not dominated by the females. The percentage of the females trapped was slightly higher in May and July, while the percentage of the males was higher in June and August. It is interesting to note that in August, at the start of the breeding period, the males were slightly more active than the females.

The main breeding period lies between August and September. This corresponds with the main period of activity. The results on figure 5 and figure 21 are in support of this conclusion. The percentage of females with immature ovaries was high in May, June and July. In August the percentage of females with developing eggs in their ovaries began to rise. Very few females had mature eggs present in their ovaries in August. Between September and October one can expect the percentage of females with mature eggs to be high.

In conclusion one can describe the life history of this species as follows: Adults emerge in April and breed in Autumn. Females lay their eggs in October. The percentage of mortality can be expected to increase in November as there is no indication of over-wintering adults. The condition of the female ovaries are shown on figure 21.

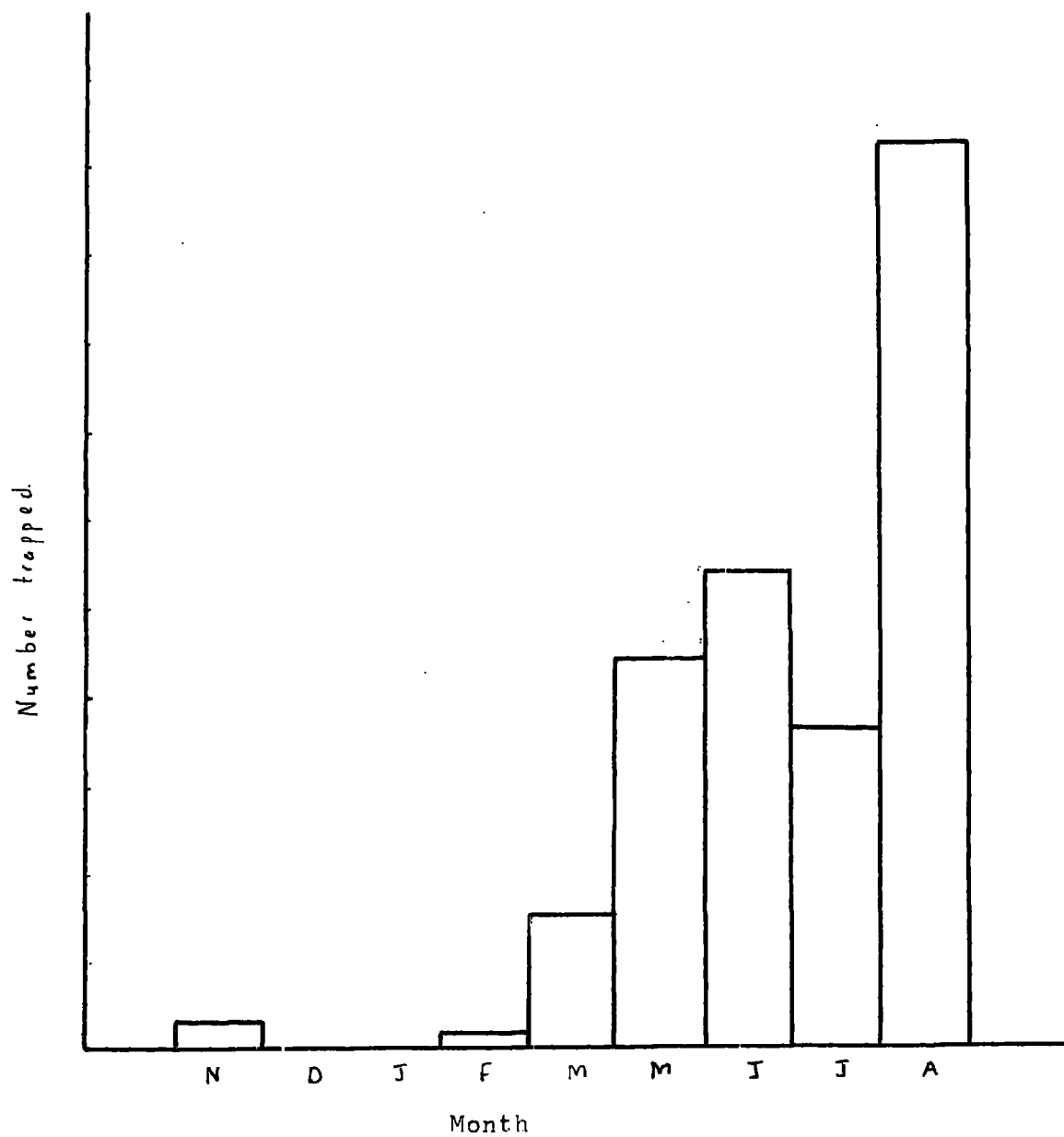


FIG 10. Monthly catches of *Tachinis pallipes* in 50 traps on the Zoological Field Station, November 1965 - August 1966.

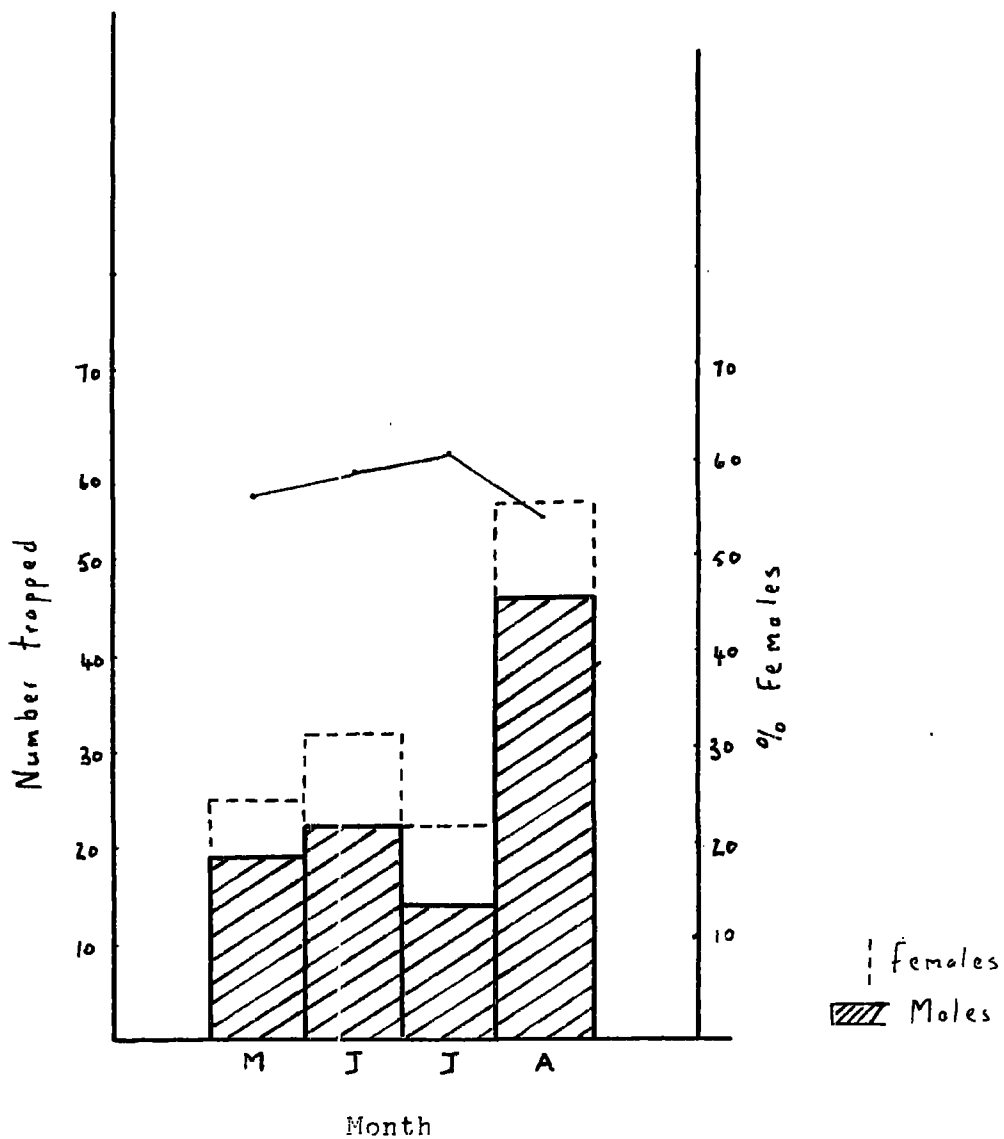


FIG 11. Pterostichus madidus : monthly sex ratio in 50 traps on the Zoological Field Station.

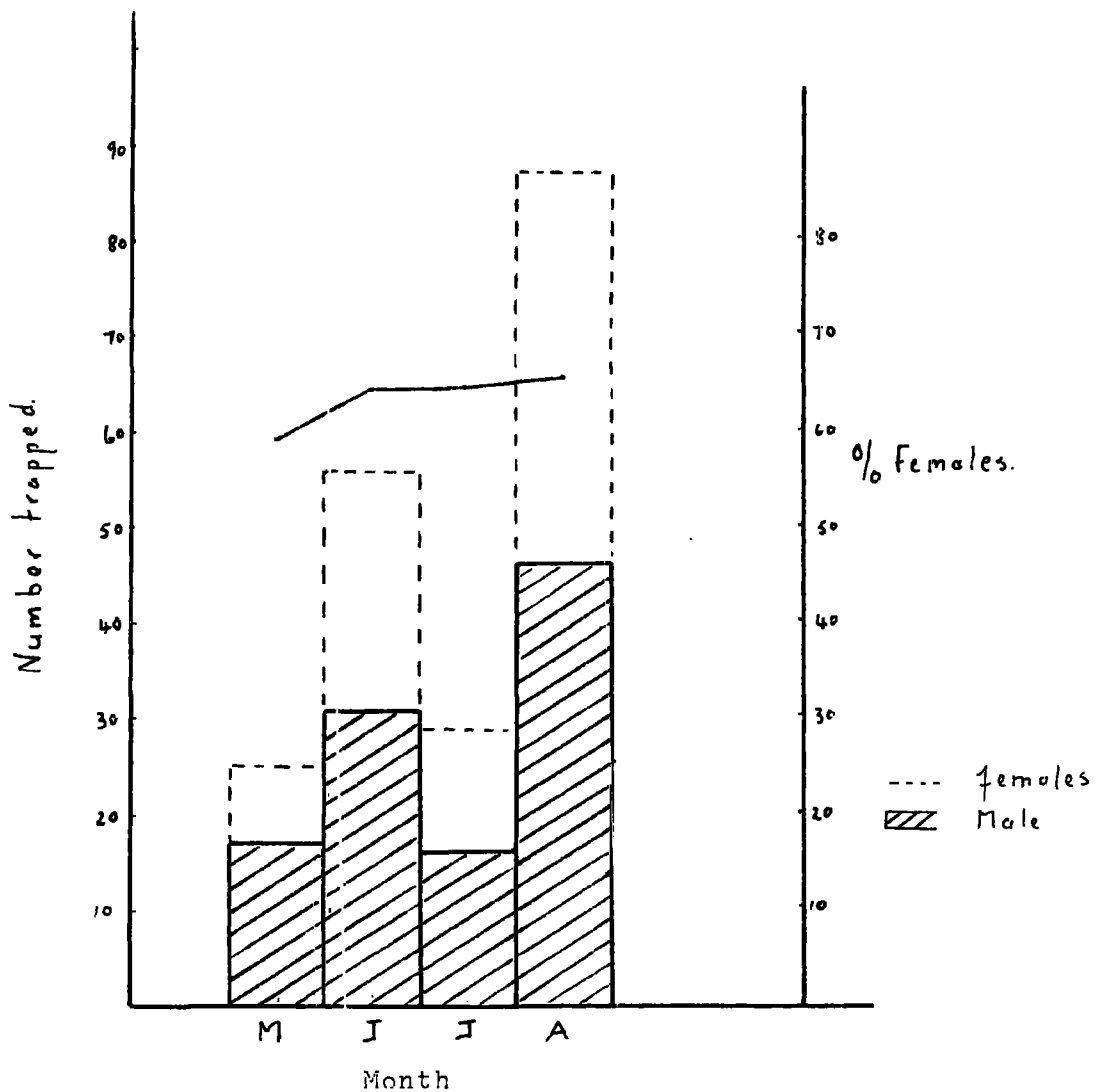


FIG 12a. *Pterostichus madidus*: Monthly sex ratio in 20 traps in Hollinside Wood.

(D) Xantholinus linearis and Quedius fuliginosus

The seasonal change in numbers of these two species is based on records of adult abundance in the traps.

Xantholinus linearis was first recorded in the traps in December. There was a steady increase in numbers thereafter. The maximum catch was made in March. From May to August there was a steady decline in numbers. One can expect the catches to be very low between August and November. No dissections were made but it is possible that the main period of activity corresponds with the breeding period.

Quedius fuliginosus was present in the traps in November when sampling began. The maximum catch was made in March. The main period of activity occurs in February, March and April.

Both species were recorded only on the Field Station (grassland). Both species occur practically throughout the year. Pitfall catches of these two species are shown in figure 4 and figure 7 respectively.

(E) Tachinis pallipes

This species was found on the field station and woods, but it occurred more abundantly in the former. The first sign of activity was recorded in March. Pitfall catches of the adults are shown in figure 10.

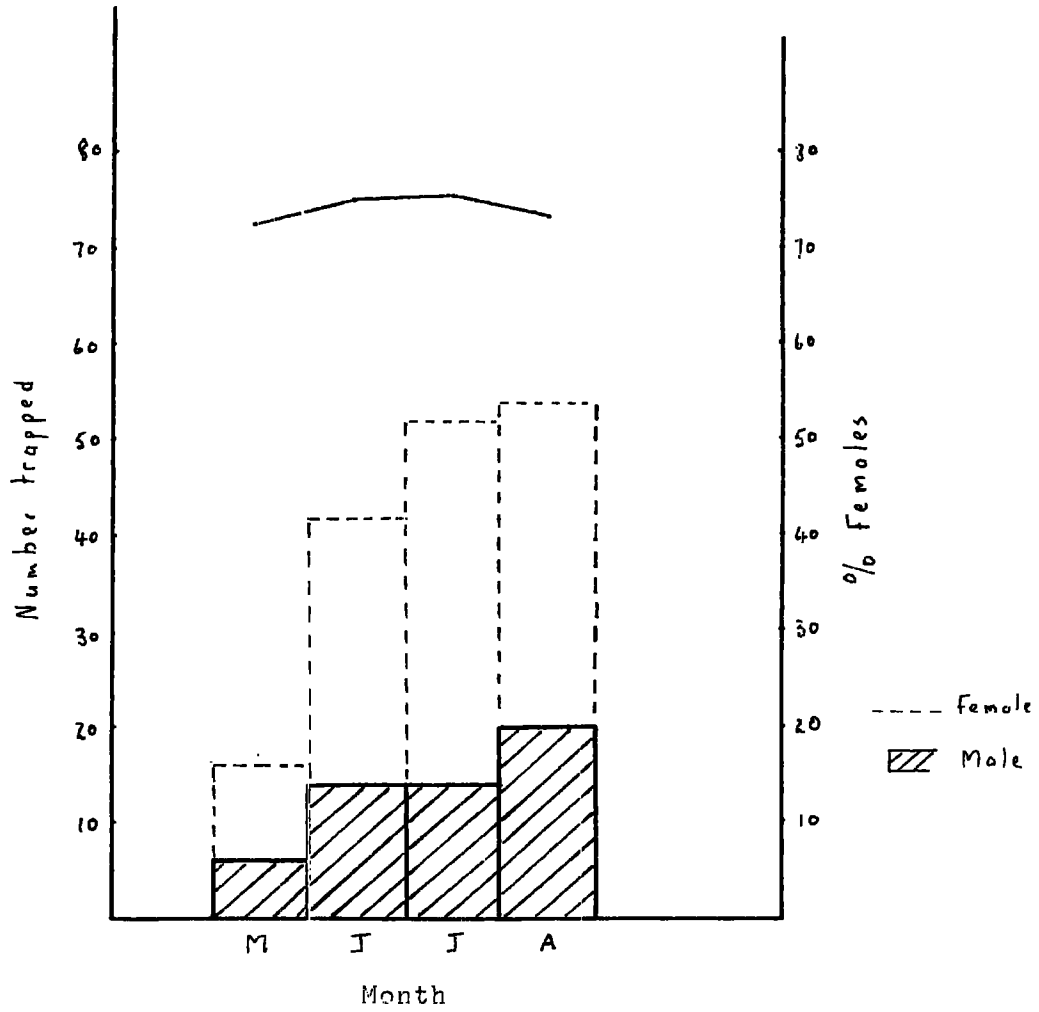


FIG 12b. Calathus piceus: monthly sex ratios in 20 traps in Hollinside Wood.

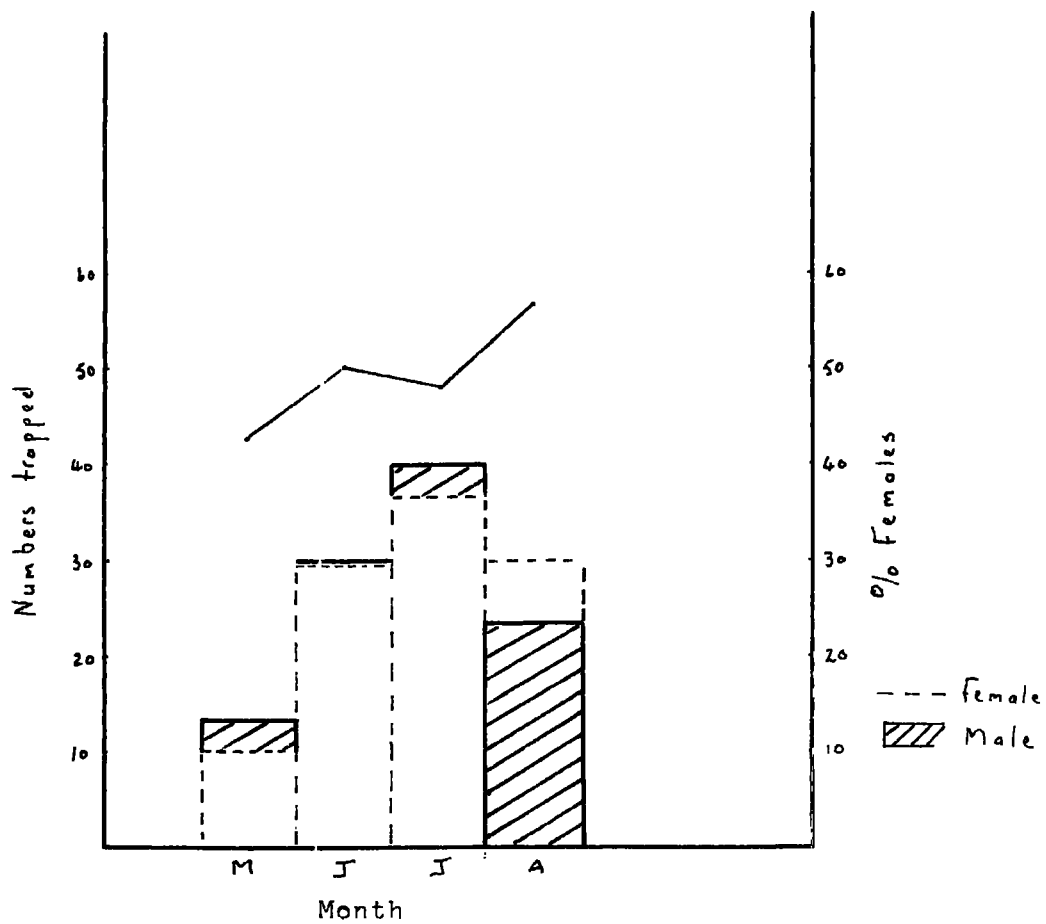


FIG 13. Abax ater: monthly sex ratio in 20 traps in Hollinside Wood.

No adults were captured during the winter months, November-February. A large number of adults were trapped between May and August. More than 900 individuals were recorded during this period. The maximum catch was made in May when 457 adults were trapped. The main period of activity was in May, June and August. In July there was a marked decline in numbers.

The period of activity in May and June corresponds with the breeding period and this is evident from figure 10 and figure 20. In March and April there was a high percentage of females with immature ovaries. In May and June the majority of the females examined had developing and mature eggs present in the ovaries. In June and July the percentage of females with mature eggs was high. In August there was again a large number of females with immature ovaries which suggests that this species over-winters as an adult. The condition of the female ovaries are shown in figure 20.

In conclusion the life history of this species can be briefly summarised as follows. The adults appear in spring and breed in late spring. Females lay their eggs in July and August. Newly emerged adults in late summer and autumn over-winters in an adult state and breeds the following year in spring.

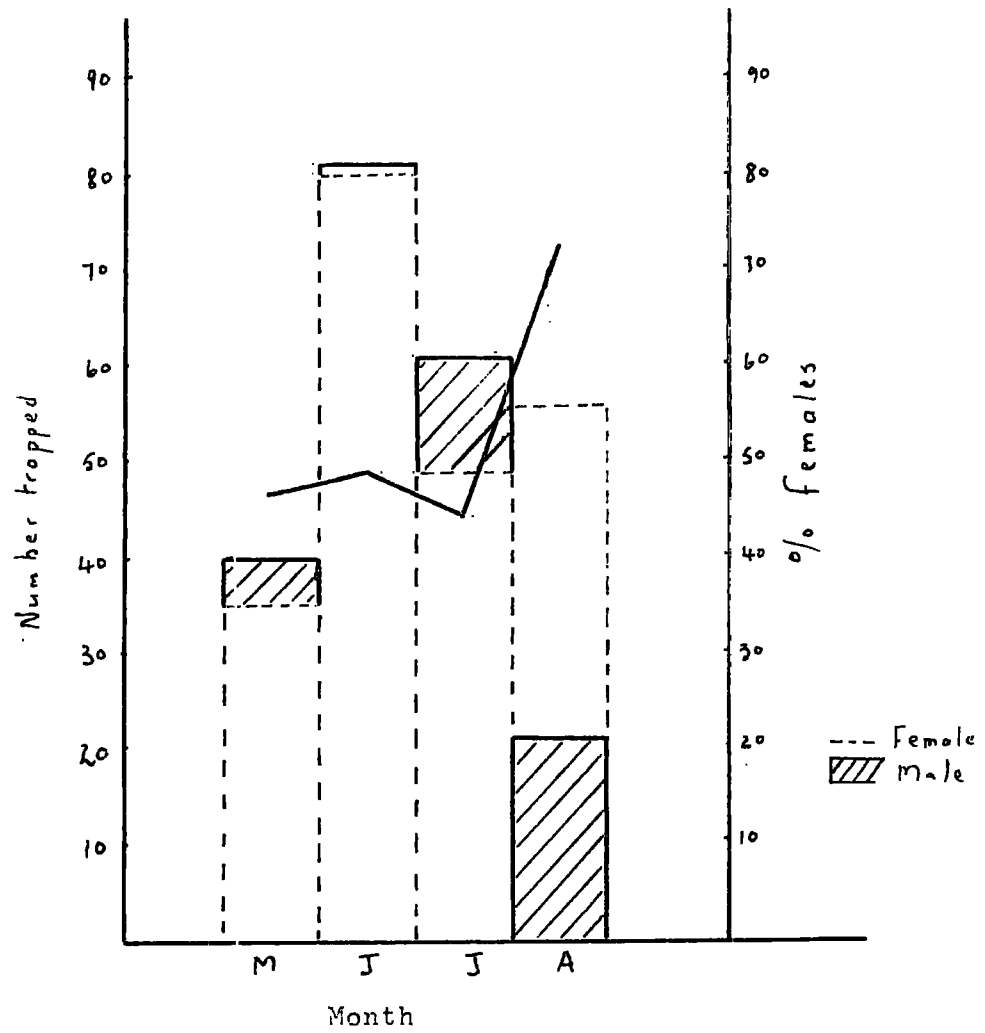


FIG 14. Pterostichus vulgaris: monthly sex ratio in 20 traps in Hollinside Wood.

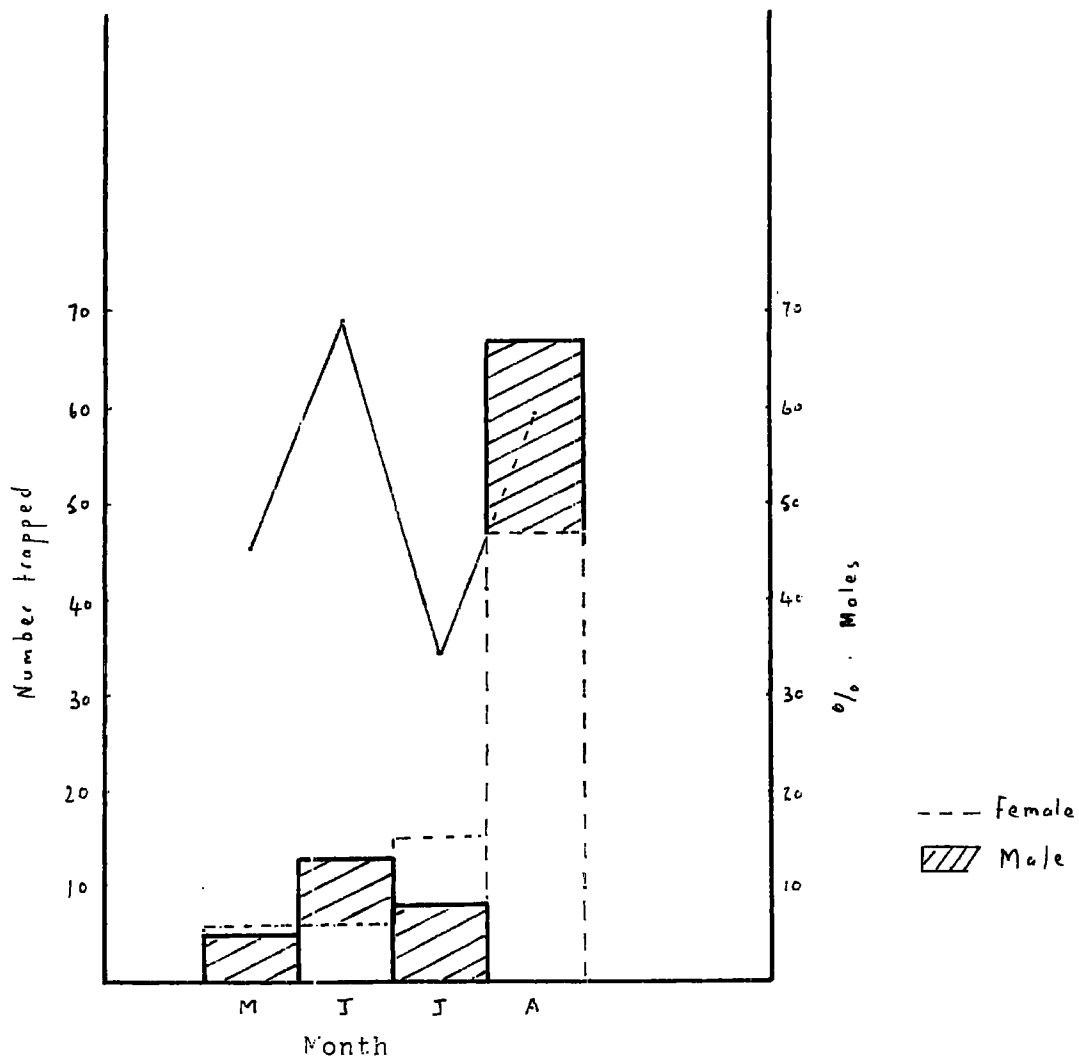


FIG 15. Carabus catenulatus: monthly sex ratio in 20 traps in Hollinside Wood.

(F) Calathus piceus

This species was captured mainly in the woods. It was not trapped in large numbers. The first evidence of adult activity was recorded in May. The maximum catches were made in June, July and August.

As shown in figure 22 the breeding period of this species occurs between June and August which corresponds with the main period of activity. The pitfall catches of the adult are shown in figure 6.

The sex ratio of this species in the 20 traps during May, June, July and August is given below:-

<u>Month</u>	<u>Number examined</u>	<u>Male</u>	<u>Female</u>
<u>MAY</u>			
5-27th	11	3	8
%		27	73
<u>JUNE</u>			
2-17th	15	3	12
%		20	80
17-31st	13	4	9
%		31	69
<u>JULY</u>			
1-10th	9	1	8
%		11	89
10-15th	9	2	7
%		22	78
15-20th	6	2	4
%		33	67

FIG. 17.

Pterostichus madidus: number caught during the day
and at night.

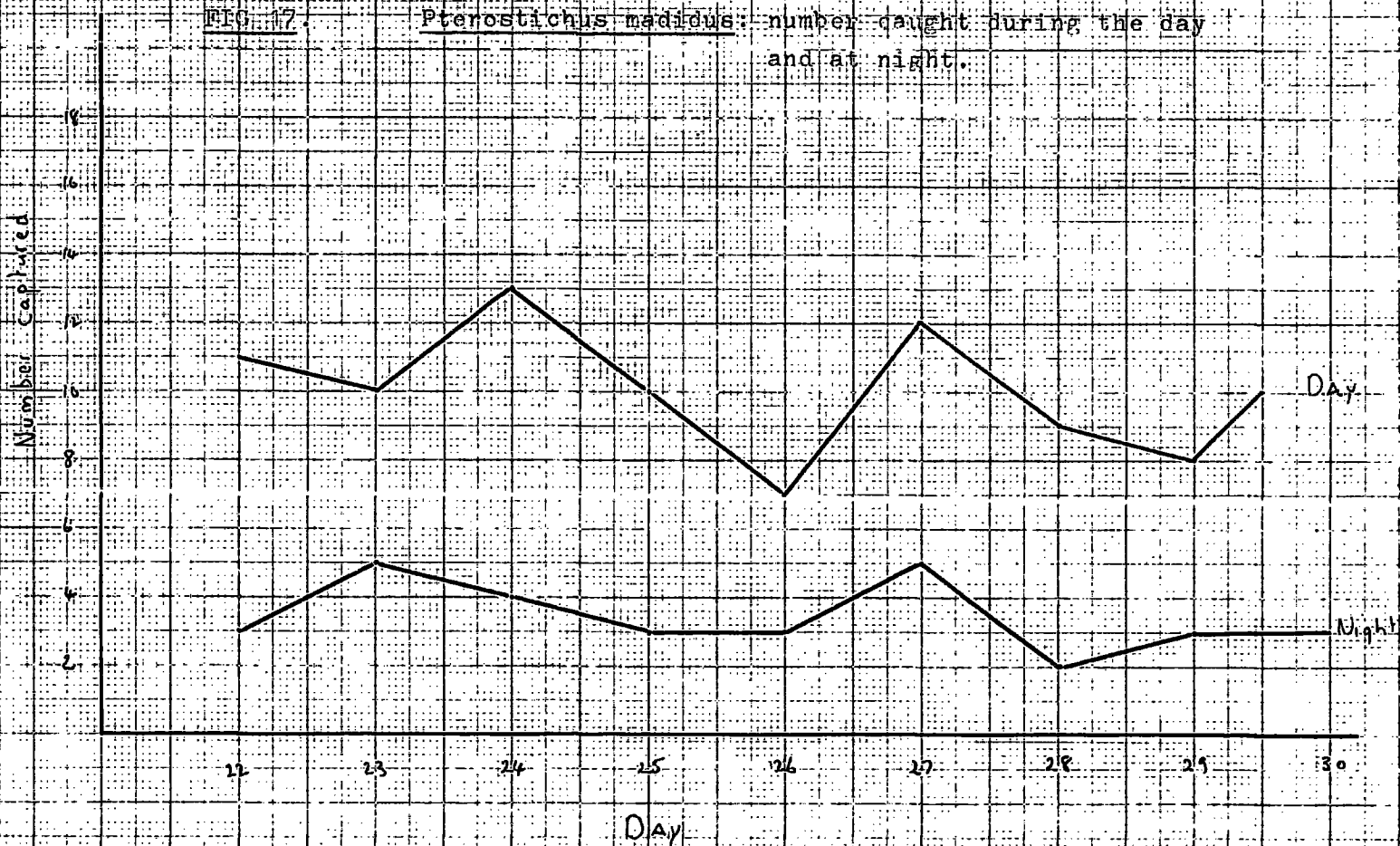
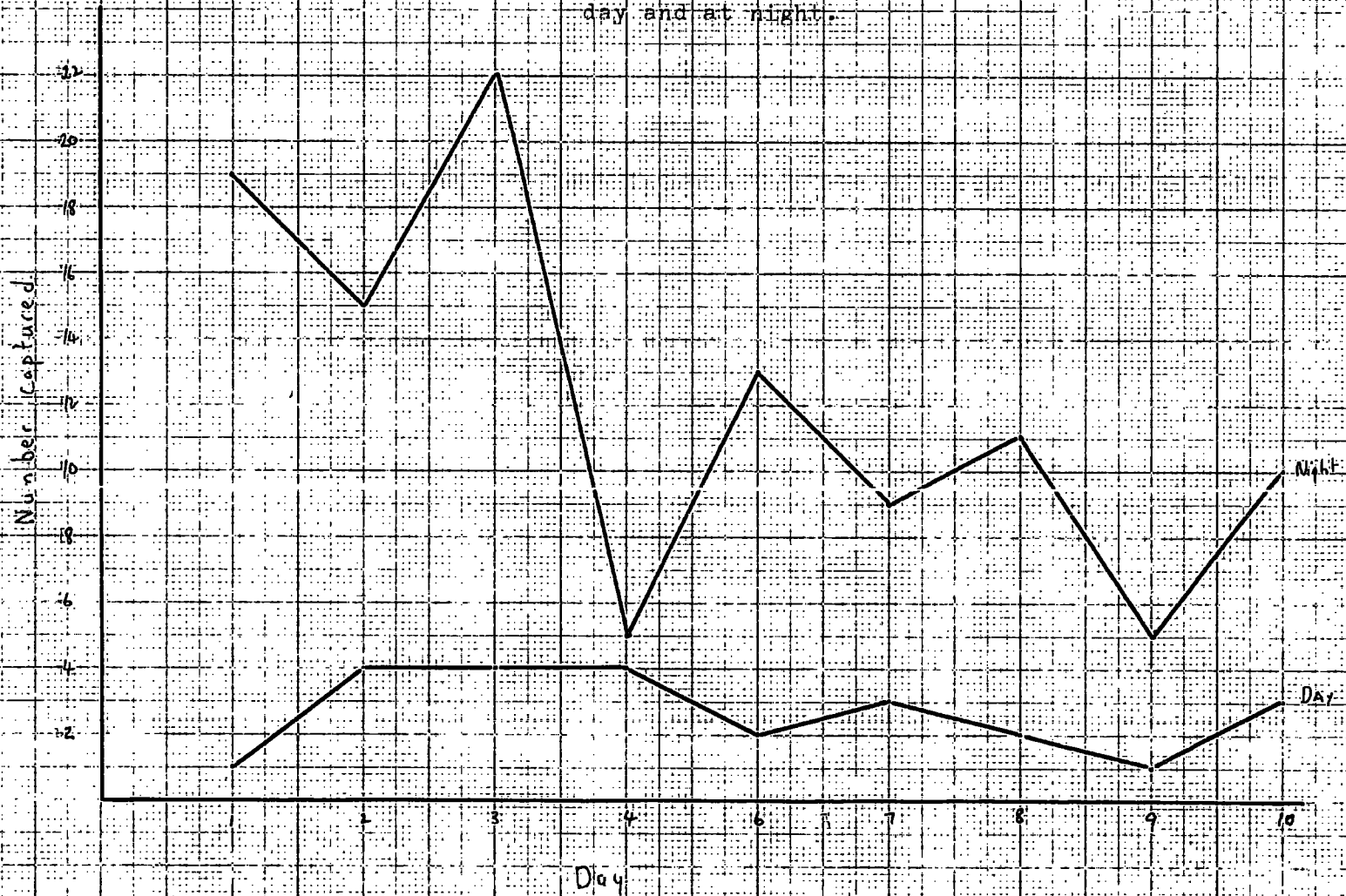


FIG 16. Tachinus pallipes: number caught during the day and at night.



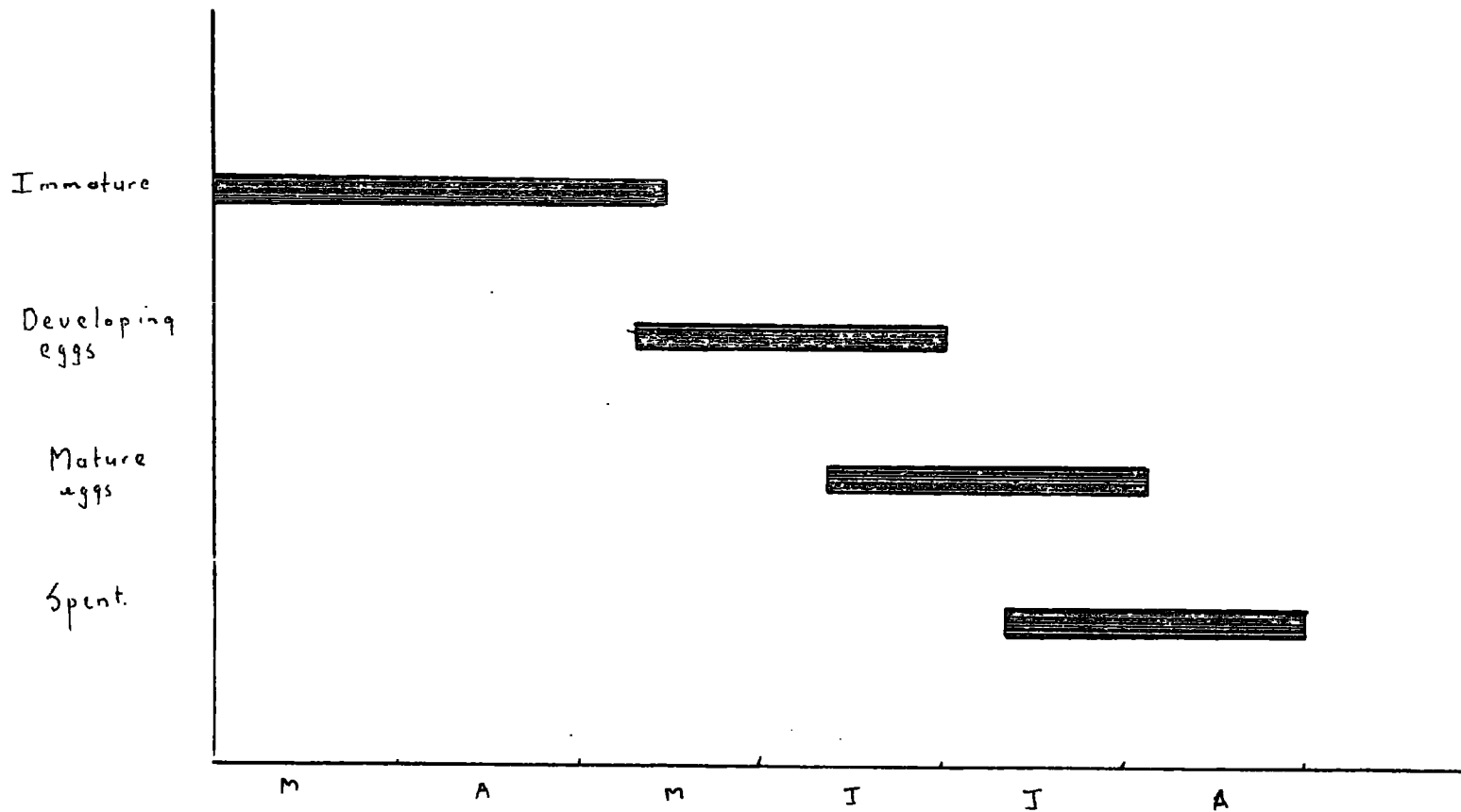


FIG 18. Ovary condition of Pterostichus madidus.

<u>Month</u>	<u>Number examined</u>	<u>Male</u>	<u>Female</u>
<u>JULY</u>			
20-30th	9	2	7
%		22	78
<u>AUGUST</u>			
1-12th	11	5	6
%		45	55
12-19th	6	1	5
%		17	83
19-26th	10	4	6
%		40	60
26-31st	10	0	10
%	—	0	100
	<u>TOTAL</u>		<u>109</u>

The monthly changes in the sex ratio are shown in figure 12b. In the four months of sampling 82 females and 27 males were trapped. Like Pterostichus madidus the activity in all four months is dominated by the females. The percentage of females in the traps increased from May onwards reaching its peak in July and August.

The breeding period occurs between May and August. Most of the females in June, July and August had developing and mature eggs in their ovaries. One can therefore expect the percentage of spent females to increase in September. The condition of the female ovaries are shown in figure 22.

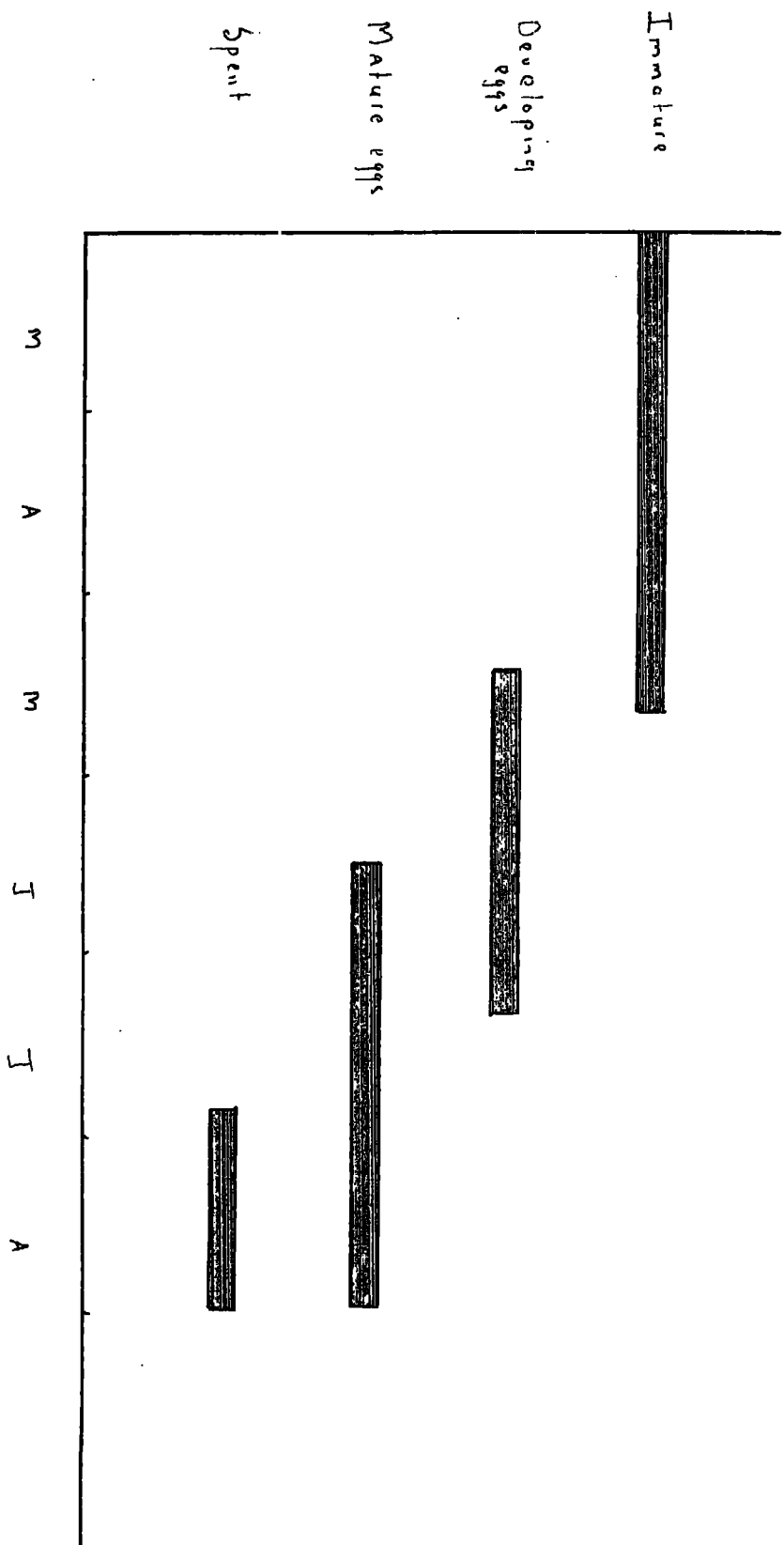


FIG 19. Ovary condition of Pterostichus vulgaris

49

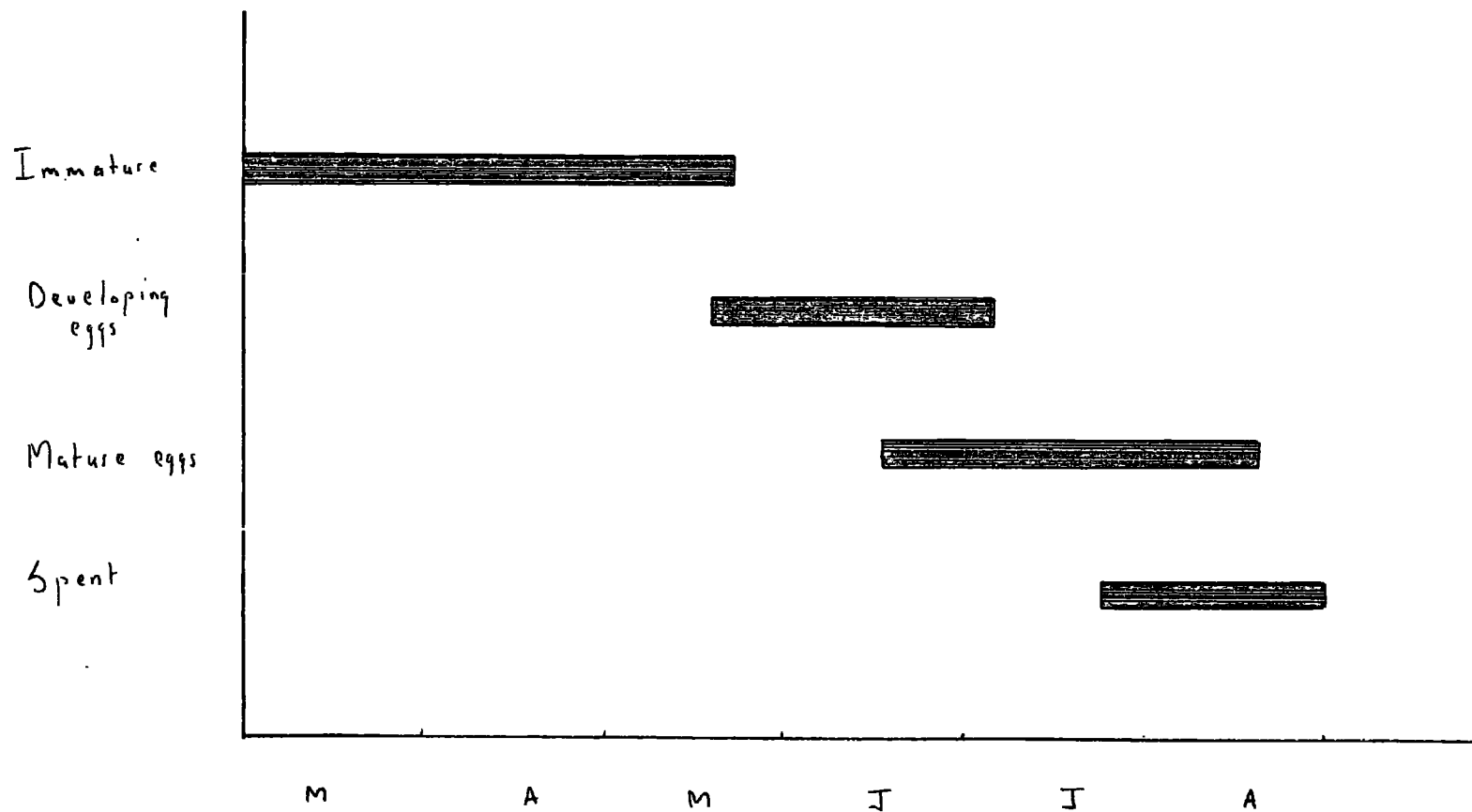


FIG 20. Ovary condition of Tachinis pallipes.

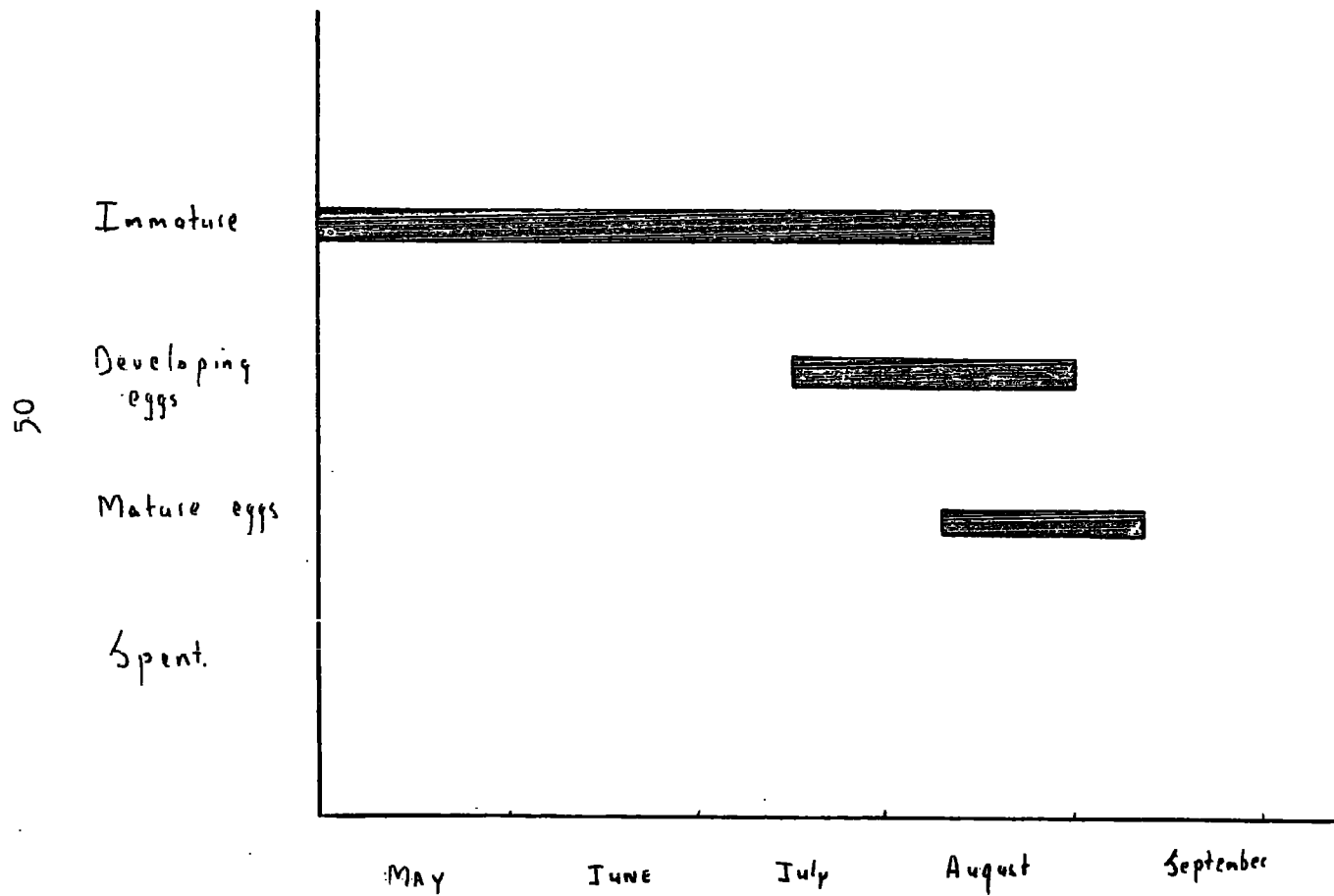


FIG 21. Ovary condition of Carabus catenulatus

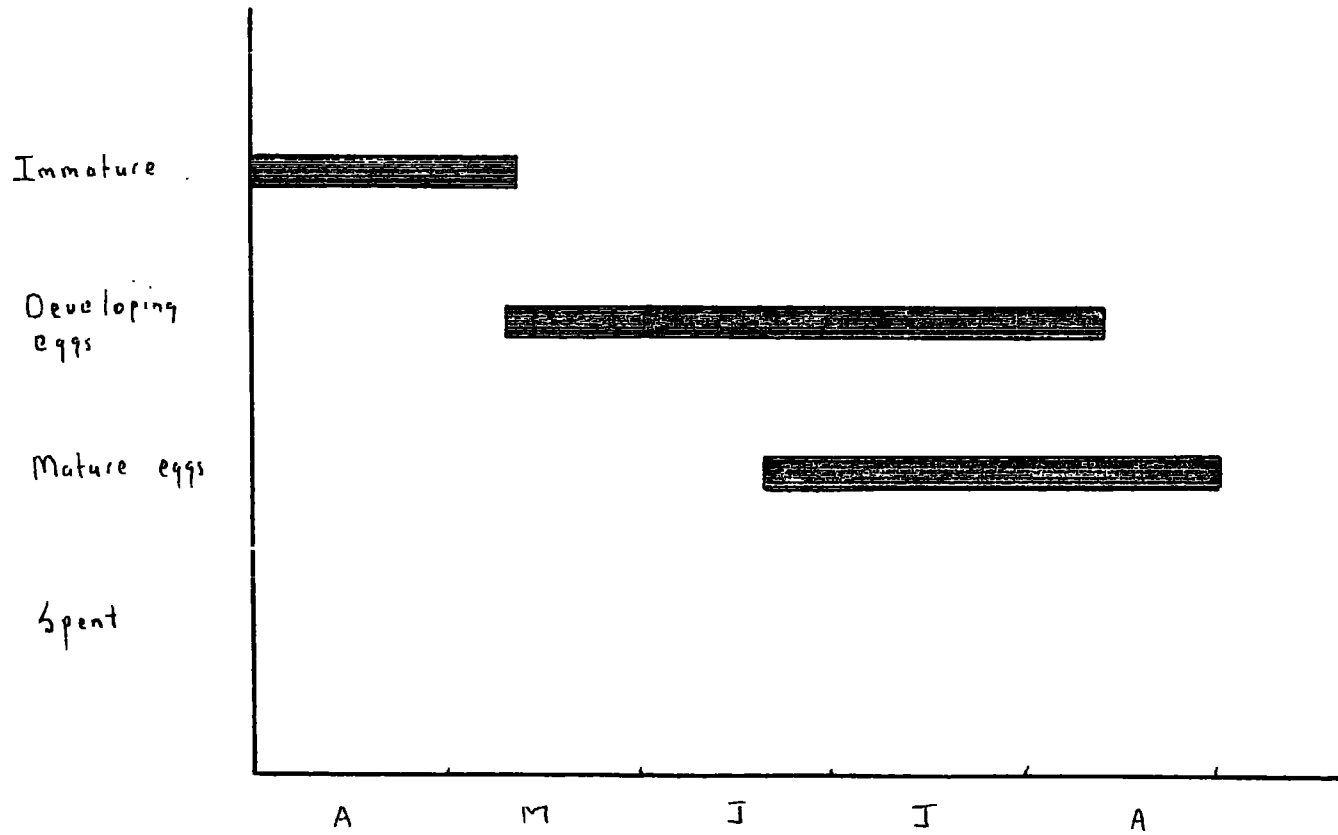


FIG 22. Ovary condition of Calathus piceus.

(G) Abax ater

This species was trapped on the Field Station and woods. The pitfall catches of the adults are shown in figures 8 and 9.

It was less common than the other Carabids and in both areas it was not captured in large numbers, but in sufficient numbers to study its life history.

The first sign of locomotor activity was in April. The maximum catches in the woods were made between June and August. On the Field Station the catches were more or less the same from May to August with a slight increase in June.

Dissection of the females showed that the percentage of females with mature eggs in the ovary was high. It is interesting to note that in May the few females examined had developing and mature eggs present in their ovaries. A high percentage of the females in June, July and August had developing and mature eggs in their ovaries.

The presence of mature eggs in the ovary in May, suggests that breeding started early in spring. It is thus possible that the adults or at least the females over-winter as adults, appear and breed in early spring, and this could account for the females with mature eggs in spring. The presence of mature eggs in the females in August suggests that breeding

also took place in summer.

The sex ratio of Abax ater in 20 traps is shown below:-

<u>Month</u>	<u>Number examined</u>	<u>Male</u>	<u>Female</u>
MAY 5 TH -JUNE 17 th	11	7	4
%		64	36
<u>JUNE</u>			
17-31 st	14	6	8
%		43	57
<u>JULY</u>			
1-15 th	9	6	3
%		56	44
15-30 th	14	6	8
%		43	57
<u>AUGUST</u>			
1-12 th	8	3	5
%		37	63
<u>AUGUST</u>			
12-31 st	8	4	4
%		50	50
	TOTAL	64	

The activity is dominated by neither sex. Both sexes were more or less equally represented in the traps. In the four months of sampling 32 males and 32 females were trapped.

Changes in the monthly sex ratio of this species are shown in figure 13. Like most Carabids the main period

of activity corresponds with the breeding period. This is evident from figures 9 and 23.

In conclusion, the life history can be summarised as follows. Adults first appear in spring. Breeding occurs early in spring and summer. Eggs are laid throughout the summer. Adults that emerge in autumn over-winter as adults, reappear the following year in spring to breed.

ACTIVITY

In June thirty extra traps were placed on the Zoological Field Station to assess the activity of Tachinis pallipes and Pterostichus madidus, i.e. diurnal or nocturnal. The traps were visited approximately every 11 hours, i.e. 8.a.m and 9.p.m.

Pterostichus madidus was found to be mainly diurnally active. In the nine days of sampling 90 specimens were captured in the traps during the day and 31 at night. The work was carried out during the summer and the traps should have been visited at 5.am. instead of 8.a.m., and therefore the night catch overlapped by about 3 hours. The total number of beetles caught at night (31) could therefore be an over-estimate. Williams (1959) Greenslade (1963) also found Pterostichus madidus to be diurnally active.

Tachinis pallipes was clearly nocturnally active. In the nine days of sampling. 109 were caught during the day and 34 at night.

55

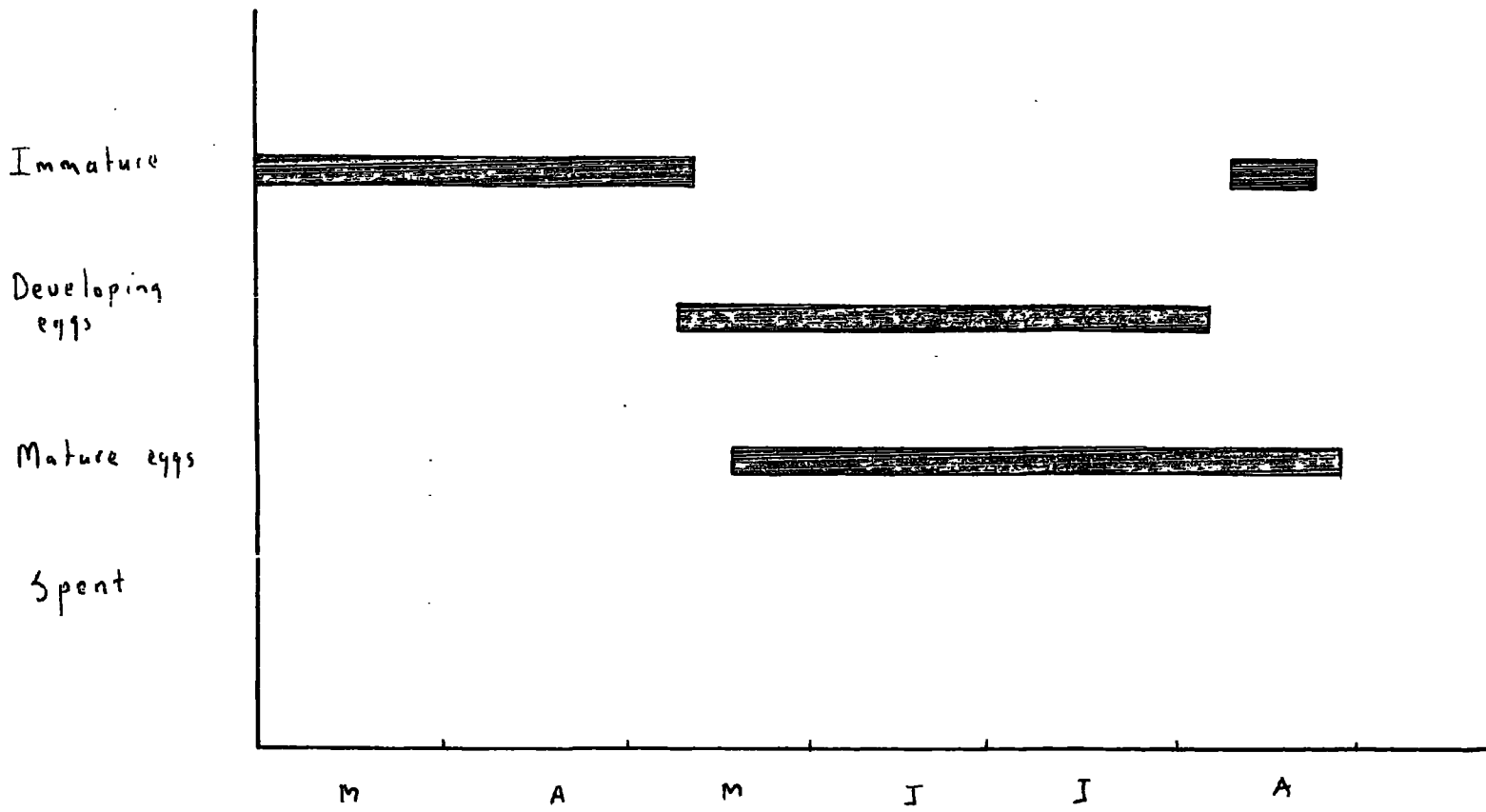


FIG 23. Ovary condition of Abax ater.

<u>Species</u>	<u>8.00.a.m.-9.00.p.m.</u>	<u>9.00.p.m.-8.00.a.m.</u>
Tachinis pallipes	24	109
Pterostichus madidus	73	30

The pitfall catches of two species during the day and at night is shown on figure 16 and 17.

BEEBLE DENSITY

Eight soil samples (0.23m² and about 0.1m in depth) taken from the Zoological Field Station in each of the four months (February, March, May and July) were extracted by Berlese funnels to estimate the density of the adult beetles.

The density of beetles was higher in winter. In February the mean number of beetles was 69.60 per m² compared with 47.42 per m² in July. The mean number of beetles found per samples were as follows:-

February	16.0	with a corresponding density of	69.60m ²
March	12.3	"	53.51m ²
May	13.5	"	58.73m ²
July	10.9	"	47.42m ²

From the 32 samples extracted the following species were common. The number caught in traps is also shown below:-

<u>Species</u>	<u>Number extracted</u> ^A	<u>Number caught in traps</u> ^B	<u>$\frac{B}{A}$</u>
Pterostichus madidus	1	256	256.0
Tachinis pallipes	14	1069	76.4
Tachinis corticinus	8	231	28.8
Micropeplus porcatus	11	76	6.9

<u>Species</u>	58		$\frac{B}{A}$
	<u>Number extracted</u>	<u>Number caught in traps</u>	
Atheta spp.	238	796	3.3
Tachyporus chrysomelinus	27	70	2.6
Stenus clavicornis	10	24	2.4

Although only two Carabids were extracted from the 32 samples compared with 376 Staphilinids, they were common in pitfall traps. The above table shows that Pterostichus madidus and Tachinis pallipes were the most active.

DISCUSSION

About 70 species of Carabids and Staphylinids were recorded on the field station and 38 in the woods. It should be noted that sampling on the field station began five months earlier.

Only three species were common in both areas, viz. Pterostichus madidus, Tachinis pallipes and Abax ater. A large number of species were recorded in both areas. A high percentage of the family Staphilinidae was captured on the field station. Some of the species were restricted to the field station and this can be associated with the vegetation cover. A list of the species is given below:-

Quedius fuliginosus

Xantholinus linearis

Xantholinus longiventris

Tachinis corticinus

Tachinis marginellis

Homalota pertyi

Stenus flavipes

Stenus corticinus

Carabus catenulates, Nebria brevicollis, Calathus piceus, and Pterostichus vulgaris were among the common woodland species but they were occasionally found on the field station traps. The same applies to some of the common grassland species, Carabus violaceus, Calathus melanocephalus, Pterostichus strenuus.

In the litter area where six traps were placed, a greater number of beetles (Carabids) were captured per trap, than in the other areas. The number of species found in these traps was limited to about five, viz. three Pterostichus species, Calathus piceus and Nebria brevicollis. Carabus catenulates was the other common woodland species, but was captured mostly outside the litter area.

Pterostichus madidus was common in both areas. A larger number of adults were captured in the woods. In the five months of sampling 331 adults were captured in 20 traps compared with 236 in fifty traps on the field station.

There are several possible reasons for this abundance and activity in the woods:-

(a) In the wood there was a thick litter layer. This usually contains a large number of cryptozoa which provides food for the beetle. This factor can be ruled out in this case as about 50% was caught outside the litter area, mainly in the grass area on the edge of the wood.

(b) On the Field Station, especially during spring and summer when this species is active, there was a thick growth of ground vegetation and this may hinder the beetles movement and hence result in reduction of pitfall catches. In the wood very little grass was present to impede beetle movement.

(c) The disturbance caused on the field station by the previous six months sampling.

In July there was a drop in pitfall catches of Pterostichus madidus. This decline in numbers occurred in both areas. This was unexpected as it was the peak of the breeding season. Most of the dissected females had mature eggs present in their ovaries. Gilbert (1956) showed that the trapping peak occurs when the population is fully matured and during the period of gonadial maturation the adults are less active than when the gonads are mature. Some investigators have shown that variation in activity during the breeding season is correlated with temperature (Briggs 1961, Murdoch 1966).

Temperature readings were not taken on the field station, but the meteorological readings at the Durham

observatory (see Table 7) about one mile from the field station show that the mean daily maximum temperature 18.7°C (65.7°F) in July was higher than in June and August. The mean daily minimum in July was only 0.5°C lower than in June and 0.2°C lower than in August. No ground frost was recorded and the percentage humidity was similar for all three months. From these observations it is unlikely that temperature or humidity was responsible for the decline in numbers. Three of the other Carabids, Carabus catenulates, Pterostichus vulgaris and Calathus piceus did not show this pattern. It is known that some beetles in their adult state undergo a period of inactivity - resting stage, but this usually occurs before the start of the breeding season. Predation by birds can be ruled out as alcohol was present in each trap. As shown on figure 1 and figure 2 the pitfall catches increased rapidly in August. The drop in pitfall catches in July could be due to some physiological factor, or some behavioural factor associated with the period before egg laying.

There are three factors which influence the beetle fauna (a) Micro-climate (b) Soil (c) plant life. Temperature and humidity of a habitat play an important part in determining beetle distribution and activity.

Tischler (1955) from his studies on different soil types concluded that the edaphic conditions have a greater influence on the fauna at the surface of the ground than the vegetation cover. He argued that since light and heavy soil differ in their structure, in humus content and in the conditions of moisture, temperature and light, it influences the whole eco-climate, and the flora and fauna also become different.

Vegetation cover, living or non-living have a marked influence on the micro-climate of a habitat. Litter and grass conserves moisture and also serves as a blanket to prevent rapid thermal changes, therefore, the daily and seasonal fluctuations will be reduced. A field soil is warmer and shows a greater range of temperature than that of the woods (Macfadyn 1963).

Greenslade (1960) found that the minimum temperature at soil surface was the same in woodland and grassland, but on the grassland the maximum temperature was 5.7°C higher than in the woods. He also observed that the maximum temperature on the grassland was reached between noon and 4.00.p.m. but in the woods the maximum was reached six hours later. This will have some effect on the period of activity, as activity is correlated with temperature. Pterostichus madidus was found to be

diurnally active on the Field Station. It has been reported that this species is nocturnally active in the woods (Williams 1959). Williams also pointed out that most Carabids are diurnally active on grassland and nocturnally active in the woods. Greenslade's above observation is in support of this conclusion.

However, some species have different periods of activity to avoid competition, as was shown by Williams (1959) in the case of Notiophilus and Nebria. Both of these are woodland species found in the litter and feed on the same type of food. To avoid competition Notiophilus is diurnally active and Nebria nocturnal.

TABLE 7SUMMARY OF THE METEOROLOGICAL READINGS AT DURHAM UNIVERSITY
OBSERVATORYMAYTemperatures

Mean daily maximum 15.0°C (59.0°F)

Mean daily minimum 5.3°C (41.6°F)

Mean 10.2°C (50.3°F)

Number of ground frosts 9.

Lowest ground temperature 2.8°C (27°F) on the 10th.

Rainfall 2.25 inches

Humidity 65%

JUNETemperatures

Mean daily maximum 18.5°C (65.3°F)

Mean daily minimum 10.0°C (50.0°F)

Mean 14.2°C (57.6°F)

Number of ground frosts 0.

Lowest ground temperature 1.1°C (34°F) on the 1st.

Rainfall 2.45 inches.

Relative humidity 63%.

JULYTemperatures

Mean daily maximum 18.7°C (65.7°F)

Mean daily minimum 9.5°C (49.2°F)

Mean 14.1°C (57.4°F)

Number of ground frosts 0.

JULY

Lowest ground temperature 2.2°C (36°F) on the 17th and 18th.

Rainfall 2.65 inches.

Relative humidity 65%.

AUGUSTTemperatures

Mean daily maximum 17.4°C (63.4°F)

Mean daily minimum 9.7°C (49.5°F)

Mean 13.5°C (56.4°F)

Number of ground frost 0.

Lowest ground temperature 1.7°C (35°F) on the 2nd and 5th.

Rainfall 4.43 inches.

Relative humidity 68%.

SUMMARY

(1) A comparison of the beetle fauna on the Zoological Field Station and Hollinside Woods was made. Pitfall traps were used.

(2) The density of the adult beetles was 69.60 beetles per m² in February and 47.42 beetles per m² in July.

(3) The life history and reproductive biology of six species were studied. These were, Abax ater, Carabus catenulates, Calathus piceus, Pterostichus madidus, Pterostichus vulgaris and Tachinis pallipes. With the exception of Carabus catenulates and Calathus piceus, they were all spring and summer breeders.

SUMMARY

Calathus piceus and Carabus catenulates were summer and autumn breeders respectively.

(4) Pterostichus madidus was diurnally active and Tachinis pallipes nocturnally active.

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APPENDIX

Bembidion lampros (Hirbst)
 Trechus quadristriatus (Schrank)
 Harpalus rufipes (Deg.)
 Feronia melonaria (Illig.)
 Agonum fuliginosum (Panz.)

Agrostis stolonifera (L.)
 Agrostis tenuis (Sibth)
 Alopecurus pratensis (L.)
 Anthoxanthum odoratum (L.)
 Arrhenatherum elatius (L.)
 Dactylis glomerata (L.)
 Deschampsia flexuosa (L.)
 Festuca rubra (L.)
 Holcus lanatus (L.)
 Miliun effusum (L.)
 Poa pratensis (L.)
 Pteridium aquilinum (L.)
 Betula pendula (Roth.)
 Fagus sylvatica (L.)
 Ilex aquifolium (L.)
 Quercus robur (L.)

