A STUDY OF CERTAIN COLEOPTERAN PESTS OF A SEMI-ARID ZONE OF RAJASTHAN WITH THE HELP OF VARIOUS LIGHT TRAPS

by

OM PRAKASH JAKHAR

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DEPARTMENT OF ZOOLOGY
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Supervisor's Note

The thesis entitled " A study of certain coleopteran pests of a semi-arid zone of Rajasthan with the help of various light-traps " is a piece of original work of Mr. Om Prakash Jakhar.

H. L. Kundu,
Department of Zoology,
B. I. T. S. (Pilani).

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Om Prakash Jakhar

(Om Prakash Jakhar)
Zoology Department
Birla Institute of Technology and Science
Pilani (Rajasthan).

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CHAPTER I

INTRODUCTION

Fluctuations in the environmental conditions regulate the activity and the number of animals. This regulation is largely affected either through the influence of the environment on the plant community which form the primary producer of any ecosystem, or directly upon the insect itself, or both. It is common knowledge to many entomologists that a good monsoon is often followed by severe outbreak of certain insect pests. Similarly, extreme summer heat or heavy winter frost is mostly followed by a conspicuous depletion of insects. Still, abundance of insects in the field when studied continuously over a period of years often fall into a regular pattern of fluctuation (Elton, 1927). However, owing to lack of sufficient experience in applying statistics in biological works, the earlier population entomologists could not assess reliably the extent to which the individual factors of environment govern such patterns of fluctuations. Williams (1937) is one of the earliest workers to use statistics extensively for assessing the extent to which certain important meteorological factors play their role in governing the flight activity of photopositive night flying insects.

Williams has worked with insects found in Great Britain and later other workers have done similar studies with insects of other places such as Egypt. So far not much has been done on this line on Indian insect pests. The present work is aimed at examining the effects of certain weather factors such as temperature and humidity on the flight activity of some nocturnal photopositive scarabaeids of Pilani. This examination will be mainly dealing with the magnitude of response that these insects show per unit change in any one factor of the components of weather. Further, a survey of the flight activity and the period of the night will also be undertaken for these insects.

CHAPTER II

REVIEW OF LITERATURE

The study of the relationship between the activity and abundance of insects with the prevailing weather conditions is an important aspect of insect ecology. Upon a proper understanding of this relationship, the forecasting of the outbreaks of insect pests largely depends. Before the beginning of the present century such relationships have been mostly studied inside the laboratories under somewhat regulated conditions (Regener, 1865; Seitz, 1891; Sajo, 1897, etc.). However, since then, various devices for trapping insects in the field have been developed and the behaviour of the insects in their natural habitats, are being increasingly studied under natural conditions.

Shelford in 1913 summarised the methods of measurement of different components of weather under which insects live. Elton (1927) showed that many populations tend to oscillate about a theoretical optimum point and such oscillations of animal population are primarily due to climatic conditions (which act irrespective of density of population). Uvarov (1931) in his extensive summary of the then knowledge of "insects and climate" stressed that climate is the ever potent factor in insect-life and that there is no escape for any terrestrial insect from such environmental factors as temperature, humidity and other conditions of habitat. Even, in those cases where the existence of an insect depends to a great extent on conditions other than climate, climate still remains a definite, if not a dominant factor.

Since the publication of Uvarov's work, more and more evidences have been collected showing the importance of weather and climate in regulating the activity and biology of insects. Allee et al. (1949) observed that one of the possible reasons for the aggregation of individuals is a response to daily and seasonal fluctuations of weather (Allee's principle). Recently Andrewartha (1954) has summarised the effects of weather on the distribution and abundance of animals. Here I propose to present a review of pertinent literature dealing with studies of insects with light-traps. Different workers used light-traps from different points of view. The earliest workers mostly used light-traps either as a device of eliminating pests or light-trap captures as indicators of the presence or the activity of insects in a locality.

The earliest records available dealing with light-trap captures is that of Marchal, who in 1912 made a study of vine moths (Clysia and Polychrosis) with light-traps. Ainslie (1917) working with crambid moths concluded that activity varies not only from species to species but also from sex to sex. Cook (1921-30) studied the activities of night flying moths. He concluded that usually light-traps do not capture more than half of the endemic moths. Hence, as an indicator of activity light-traps have definite limitations. Cook also found that light-traps situated above a certain height from ground level (on the window in the third storey) capture mostly migratory insects but not the local ones. King (1928) used light-trap for the control of the moths of red bollworms of cotton. Bogush (1936 and 1951) used light-traps as tools for studying the dynamics of abundance of insects in Soviet Central Asia. Merkl and Pfrimmer (1956) used the captures as indicator of the outbreaks of an insect pest (Platyedra gossypiella). Similarly Hallage (1927) used the traps for destroying Scythris temperatella, Sakharov and Strukov (1927) for Noctuidae, and Smith and Allen (in the same year) against spotted cucumber beetles. Kaburaki and Kamito (1929) also found light-traps very efficient in controlling Chilo simplex.

However, the efficiency of light traps for eliminating pests is not always high. Smith and Allen (vide supra) found light-traps not very promising in controlling cucumber beetles. According to Parrott (1927) the destructive insects caught in the trap are too few to affect the population.

Light-trap captures have been used successfully by many to survey the rhythm of activity of insects. Hassanein (1956) found that Prodenia - a pest of cotton and clover, has a peak of activity in June and July and five overlapping broods with males always outnumbering the females. Collins and Machado (1943) found light-trap captures providing detailed knowledge of the habits and behaviour of codling moths. Tashiro and Tuttle (1959) found light-traps extremely efficient in capturing chafer beetles. Even during the season although none were seen active during day time, light-trap captured as much as seventy times more than traps with chemical baits.

However the efficiency of light-trap is an extremely variable factor, much depending on the nature of the light, the construction of the trap and the height at which it is situated and so on. Williams, French and Hosni (1955) compared the trap-types and illumination and concluded that 125 watt mercury vapour lamp gives catches that are far from one and half to three times as large as those with 200 watt ordinary bulb. Further, Robinson trap is definitely better for catching the heavier and strong flying insects, while for the smaller insects the Rothamsted type is superior. Weber (1956) showed that by specially designing the light-trap it is possible to control Cydiapomonella - a serious pest of apple.

Gradually it became increasingly apparent to the workers with light-trap captures that, while the magnitude of an insect population may be regulated by the preceding climate the abundance of the captures in the trap is very much dependant upon daily fluctuation of weather. Many have worked on this. Yothers (1927) noted that codling moths were most active when daily mean temperature was near about 70°F. The activity practically ceased with a sudden drop of temperature but was resumed again by gradual rise of it. Collins and Nixon (1930) concluded that in lepidopteran flights are definitely inhibited when temperature fell below

70°F. However the threshold for this inhibition is variable from species to species, as well as from latitude to latitude. For codling moths it is 60°F (Parrott and Collins, 1934). But for European corn borer it is 65°F (Stirrett, 1938). Juillet (1960) noted that if relative humidity is high (80 to 100%), ichneumonids are most active between 70 to 75°F. Similar to temperature there is also an optimum level for humidity for the flights of insects. This level is specific. Hussain (1930) first noticed that the activities of *Dysdercus cingulatus* is influenced by humidity and temperature. Beal (1938) concluded that the number of moths and the daily maximum temperature are positively correlated but not so with evening humidity. Stirrett (1938) also observed that there was no correlation between humidity and catch.

Williams (1939-40) made an extensive study of light-trap captures, collecting continuously for four years. Using appropriate statistical techniques he brought to light many information about the flight activity of photopositive nocturnal insects which were heretofore either unknown or vaguely understood. He demonstrated the quantitative relationship of capture and changes in weather. The effect of the minimum temperature, considered alone, is that the catch is doubled by an increase in minimum temperature of 5°F or with a rise of 7°F in the maximum temperature. The relative humidity at 9 P.M. shows a small but probably significant regression of about 0.008 change in log. catch produced by 1% change in humidity.

Ziady and Osman (1961) studied the effects of various weather factors on the activity and abundance of dipteran at Cairo and concluded that the activity is mainly controlled by the combined effects of temperature and wind velocity.

With regard to the effect of moon light and the period of night, upon the captures, observations of different workers vary. Kanbe (1928) stated that moths of pink bollworms of cotton are most active between 1 to 3 A.M. (July to September). Robertson (1939) working with crane flies (Diptera) noted that the activity was the maximum immediately after sunset, it remained declined till mid-night, after which it remained steady till sunrise prior to which there was a slight increase. With Hemerobiidae, Banks (1952) found that activity is the maximum between 9 to 11 P.M., reaching the peak between 9 to 10 P.M. Hora (1927) believed that emergence of may flies (Ephemeroptera) has got definite relationship with moon light. In the same year King observed that attraction of moths to light becomes appreciably less in bright moon lit nights. Moon light is also one of the factors which influence the activities of the vine moths and aphids (Takagi, 1933 and Broadbent, 1947) respectively. In 1951 Williams and Singh observed that there is a definite relationship between insects' activity and moon light and the low catches at full moon light and the peak of activity shortly after new moon be due to the lower luminosity (light-trap) at full moon night. In 1956 Williams, Singh and Ziady stated further that there is no definite evidence of an effect of moon light on activity of night flying insects. Very likely the reduced catch in the full moon nights is due to the reduction of the relative illumination of the trap. Ziady and Osman (1961) also made similar observations as they could not find any definite lunar periodicity in the flight activity of insects any more.

Sex influences flight. Ainsle (1917) found that the males of crambid moths fly actively throughout the night, while the activity of the females were mainly determined by the physiological state of ovaries. While working with codling moths, Yothers (1927) found that the females dominated the catch and 95% of them were gravid. The females of Chilo simplex are more attracted towards light before mid-night and males after mid-night (Kaburaki and Kamito, 1929). With regard to vine moths Takagi (1933) made similar observations and found that females were more attracted in early hours of night. The photopositiveness of the females of codling moths decrease after oviposition (Parrott and Collins, 1934). Hassanein (1956) in his extensive study of Prodenia with light-traps in Egypt, noted that the males always exceeded the females. Tashiro and Tuttle (1959) made an interesting observation with European chafer beetles. They found that females exceeded the males in light-trap captures but opposite results were obtained with chemical bait trap. Amongst Simuliidae males formed a higher proportion than females when the catch is abundant (Davies and Williams, 1962).

Insects response to different wave lengths of light is not uniform. Kanbe (1928) by collecting moths of pink bollworms with different lights showed that 70.4% catch was made with purple light as compared to 17.5% by white light 10.3% by green and 1.8% by red light. Similar observations were made by Peterson, Hacussler and Yothers (1928) who concluded that if free choice be given, moths prefer blue and violet lights. Kaburaki (1938) stated that ultra-violet rays are most effective in attracting insects. Frost (1953-59) also made similar observations. However according to him mirids and chrysopids responded more freely to white light than purely ultra-violet. Schwemberorrego (1959) also made experiments about the preference of ruteline to various colours and intensities of light and found that they were attracted in the descending orders of various shades of red, blue and green. Kundu (1960-61) used two traps at Pilani (Rajasthan), one with a 100 watt electric bulb and the other with a 90 watt U.V. spectral lamp. He has found that the latter was 2-3 times more effective than the former. Glick, Graham and Hollingsworth (1961-65) published a series of papers on light-trap captures of <u>Pectinophora</u> <u>gossypiella</u>. They have found that traps equipped with argon glow lamps are much more efficient in attracting insects than the traps fitted with conventional electrically fitted traps.

Still it is reasonable to assume that not all the night flying insects visit and are captured by light traps. However, the efficiency of the trap can be much improved by using light of appropriate wavelength coupled with changes in the design of the trap. As early as 1927 Parrott noted that the catch depends upon the type of the source of light, its intensity, the height at which the trap is operated and if any attractant has been used. Williams (1939) designed a light trap specially constructed and had a 200 watt source of light. Since then this is being widely used in many places. In 1951 Williams made a comparison of the efficiency of the various traps by converting the catch into logarithmic scale and by analysis of variance. He succeeded in isolating the effects of locality from the effects of the nature of the trap upon the captures. Robinson (1950) designed a trap with a 125 watt mercury vapour lamp (instead of 200 watt ordinary electric light bulb in Williams's) and found it much more attractant of insects than Williams's. In 1956 Williams, French and Hosni made a careful comparison of the efficiency of these two traps and concluded that 125 watt mercury vapour lamp gives catches that are from one and a half to three times as large as those with 200 watt ordinary bulb. They contend that the Robinson trap is definitely better for catching the heavier and stronger flying insects, while for smaller insects the Rothamsted type is superior.

So far this review dealt with the works carried out in U.K., Egypt, Europe, Japan and America. Interest of Indian workers in this area of investigation is fairly recent.

Since the beginning of this century, agricultural Entomologists in India have been trying to make use of the photopositiveness of many insect pests. Lefroy (1909) discussed the light trap as one of the simplest and efficaceous methods to obtain insects. He has noticed that intense white light always attract a large number of insects and yellow oil lights attract fewer insects. According to him amongst the scarabaeids, melolonthine, dynastine and coprine usually come to lights. Lefroy however ascertained that although the use of lights and light traps has been a favourite method with agriculturists in dealing with certain classes of pests, it is not always ascertained if the pest to be captured does really come to the light freely. Ramakrishna Ayyar and Anantanarayanan (1934) found that many insects are highly photopositive at the emergence of every fresh brood. This photopositiveness remains sufficiently pronounced even in moonlit nights. Hussain, Haroon Khan and Ganda Ram (1934) have observed however that Platyedra gossypiella catch is decreased in moonlit nights. They have also noticed that the catch is most abundant between mid-September to mid-October and at a temperature between 76-87^{o}F. Usman (1954, 1955 and 1956) prepared a list of insects which visited an electric light through a window. He listed altogether 154 species of insects consisting Lepidoptera, 83; Coleoptera, 23; Hemiptera, 17; Hymenoptera, 12; Diptera, 8; Orthoptera, 5; Dermaptera and Isoptera 2 each and Ephemeroptera and Embioptera one each. Shull and Nadkerny (1964 and 1967) prepared another list of the insects that come near a lamp-post (with a fluorescent bulb) at Ahwa, Gujrat. They listed 450 species altogether consisting of Lepidoptera, 239; Coleoptera, 79; Hemiptera, 55; Orthoptera, 37; Hymenoptera, 10; Diptera, 9; Dermaptera and Dictyoptera, 6 each; Odonata, 5; and Neuroptera, 4. There was a considerable ultra-violet element in this light. Ultra-violet rays attract insects very strongly.

None of the above workers however used "light traps" designed especially to capture insects. Banerjee and Basu (1956) installed a Rothamsted type light trap (the type used by Williams in U.K.) at Chinsura, West Bengal to study the behaviour of the insects. Mukerjee (1961) used captures from this trap to study the activity and phenology of the following lepidopteran borers

Schoenobius incertulas
Scirpophaga gilviberbis
S. sp.
Cnaphalocrocis medinalis
Diacrisia obliqua
Utitheisa pulchella
Creatonotus gangis
Amsacta lineola
Naranga diffusa
Anthena servula
Euproctis varians
Laelia testacea

Kundu, Datta Gupta and B.B. Gupta (1961) published a note summarising a few months' work with a light trap at Pilani, Rajasthan.

CHAPTER III

MATERIALS AND METHODS

(a) Insect species

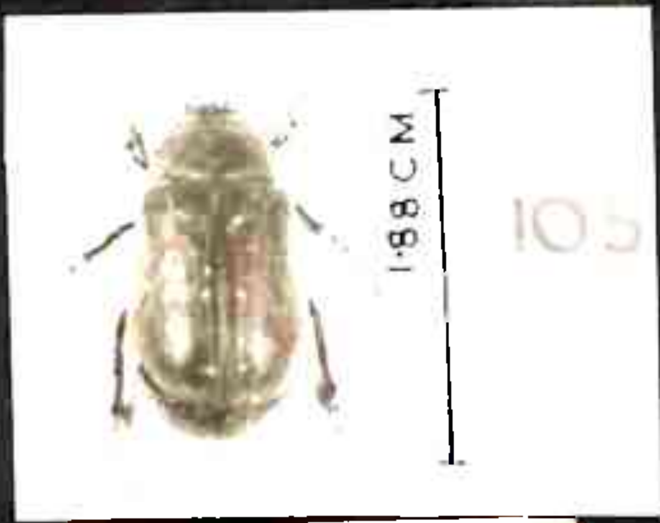
Out of 60 species of scarabaeids, so far collected from the light-trap captures at Pilani, 8 species have been selected for this investigation. This choice has been made due to following reasons:

Firstly, they are easily recognisable in large collections, secondly, their abundance in trap captures and lastly due to their activity spread over longer period. It is observed that very small insects whose identity can easily be confused with others (unless examined very carefully) or insects which are scanty in the captures or insects whose flight activity is very sporadic and narrow offer poor materials for this type of work. Considering all these aspects, the following sps. have been selected for study:

TABLE 1(a)

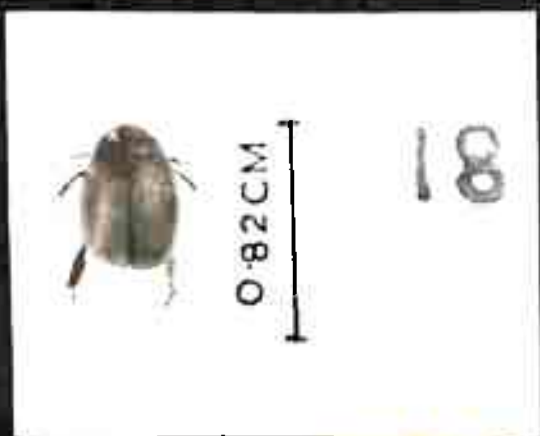
Species		Av. Length (cms.)	Av. Weight (gms.)	L.T Coll.No.
Melolonthinae				
Holotrichia seticollis	(F)	1.88	0.633	105
Schizonycha ruficollis	(F)	0.94	0.084	90
Autoserica insanabilis	(Brsk)	0.82	0.053	18
Apogonia ferruginea	(F)	0.81	0.046	26
Rutelinae				
Anomala ruficapilla	(Burm)	1.17	0.157	106
Adoretus compressus	(Weber)	1.12	0.108	40
Adoretus lasiopygus	(Burm)	0.92	0.056	131
Coprinae				
Catharsius pithecus	(Hope)	1.28	0.237	87

L.T. Coll. No. stands for light trap collection number



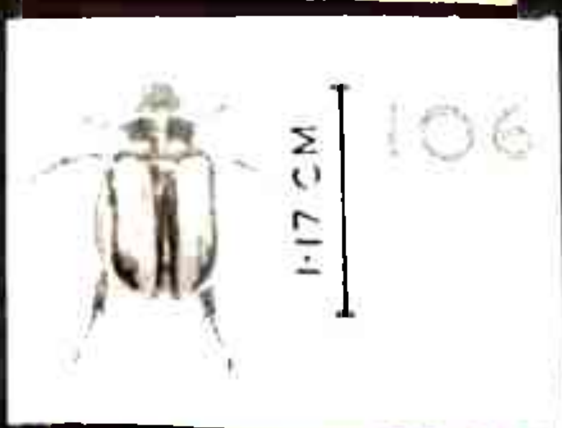
Holotrichia seticollis

Schizonycha ruficollis



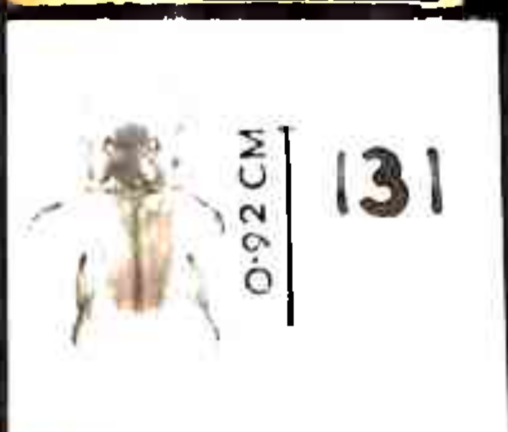
Autoserica insanabilis

Apogonia ferruginea



Anomala ruficapilla

Adoretus compressus



Adoretus lasiopygus

Catharsius pithecus

However, both the period of captures and the relative abundance of each species in traps, vary considerably. The following synoptic table will illustrate this point.

TABLE 1(b)

Species	Mean annual captures	Period of captures
A. lasiopygus	50529	May to October
S. ruficollis	8578	May to September
C. pithecus	6995	May to October
A. compressus	3988	April to August
A. ferruginea	2394	March to October
H. seticollis	1868	May to October
A. insanabilis	1723	March to October
A. ruficapilla	272	May to August

(b) Handling of captures

The daily captures of each species in each trap have been recorded separately. Daily captures of each species have been converted into 5 day running means. For statistical analysis the logarithm of catch number is used instead of the actual number itself. To overcome the difficulty of zero catch, unity has been added to each of the catches before taking the log.

A knowledge of the biology of these scarabaeids would have been very helpful in understanding their activities but as far as I could gather from the existing literature the biology of Indian scarabaeids is very inadequately known. Besides, the biology of the same species varies from latitude to latitude (vide infra). Moreover, scarabaeids are extremely difficult to rear in captivity and the life histories of many of them are multi-annual. These have contributed towards the paucity of data on the biology of oriental scarabaeids. However, all the available information regarding the biology of scarabaeids referred to in this work, are those which are very close to these species, has been collected from the existing literature and summarised separately.

(c) Light traps used

This work has been conducted with the help of three light traps which captured insects daily. The construction of the trap is as follows:

A tin funnel of 18" height, suspended about 4' from the ground, has a 100 watt electric bulb about 6" above the mouth and a large glass jar firmly pressed against the spout. The whole assembly is supported on a suitable wooden frame fixed in the required position in the field and with a tin top on the frame (Plate 1). Later, metal frames were used instead of wooden frames (Plate 2).

All the traps are stationed at different spots, well away from the sphere of influence of each other. One trap called light trap "K" is located at the garden of Dr. H.L. Kundu, another trap "B" is located within the Botanical garden of the Institute and the third trap called "E" is located by the side of semi-dry grass land within the compounds of the Central Electronics Engineering Research Institute. The position of the traps are indicated in the map (Fig. 13).

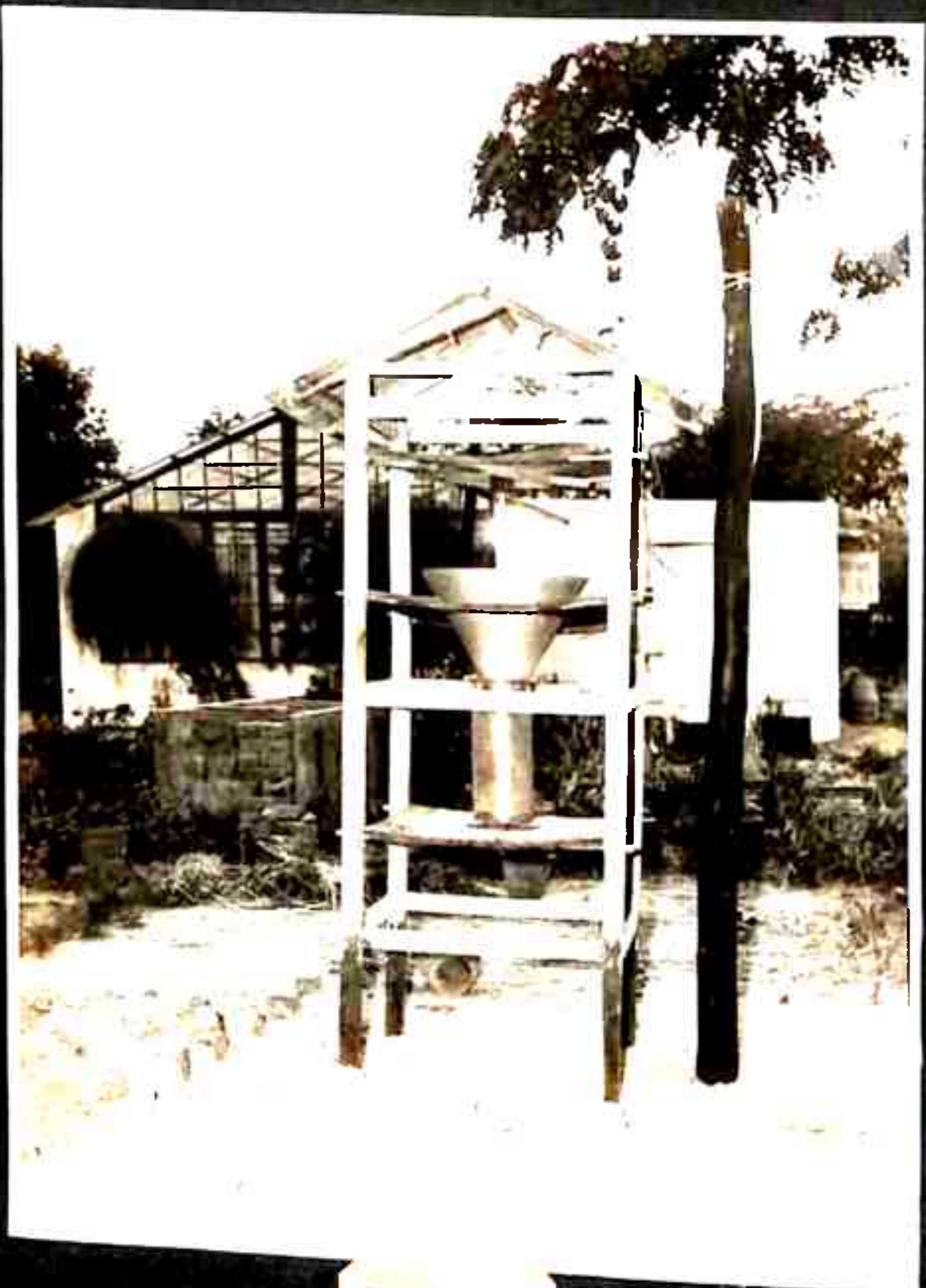


Plate - 1

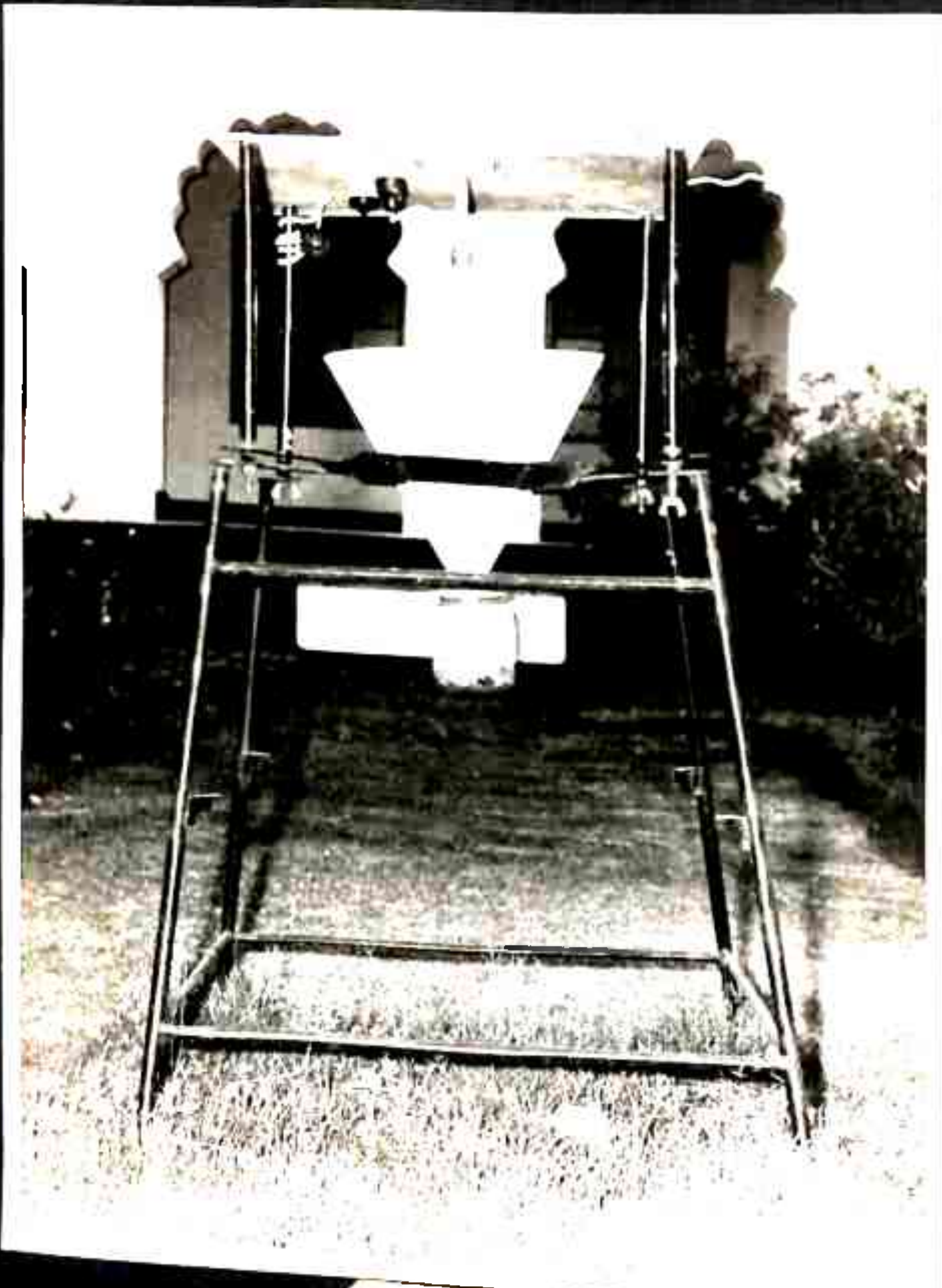
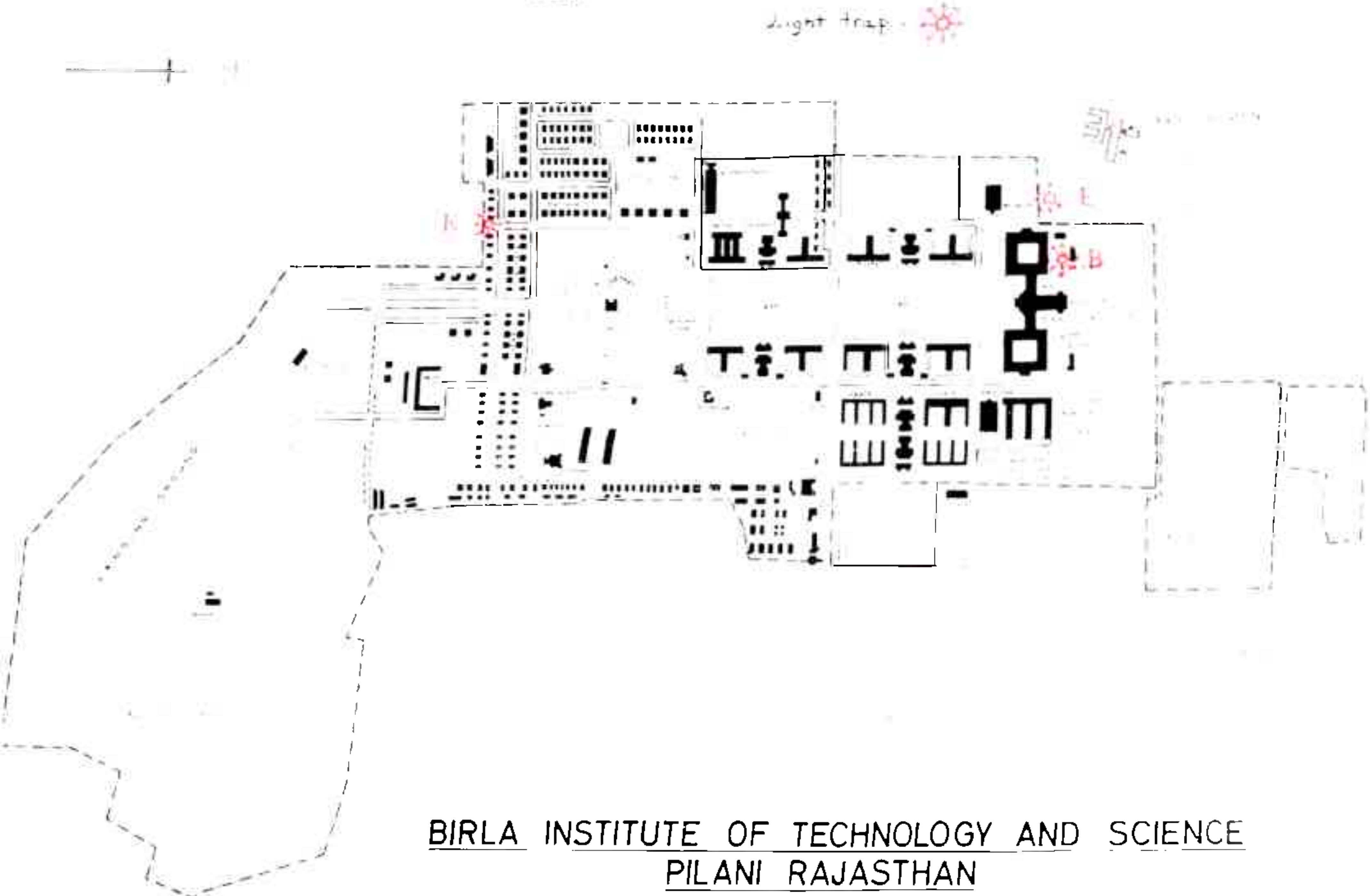


Plate - 2

Fig. 13



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It will be noticed that these traps are somewhat modified from the traps used by Williams at Rothamsted. Williams' traps, owing to the large number of glass components in them, are difficult to maintain uniformly in the field conditions at Pilani over a long period. Hence, this modification in construction was deemed necessary. As the traps used here are all of the same type, the data of captures of all these traps should be sufficiently comparable.

(d) Operation of the traps

All the traps have been operated daily from 1963 to 1966. The lights are switched on before sunset and switched off after sunrise. The insects captured in the jar are chloroformed in the morning, brought to the laboratory and are sorted into different species. The total number of each species are recorded daily. Captures of each trap are also recorded separately.

In order to find out the fluctuations in flight activity of these scarabaeids during the different periods of night, captures of trap "B" have been collected at every three hourly intervals (9 P.M., 12 M.N., 3 A.M., 6 A.M.). Such collections have been made in every week during 1965. In that particular night chalk sticks soaked in tetrachloro-ethane were put in the jar. The vapours from tetrachloro-ethane act as killing agent and thus minimised the chances of escape of the insects from the jar.

(e) Meteorological data

For meteorological data two sources have been used. From one source the daily record of the fluctuations in temperature and humidity in the field with the help of a thermograph and a hygrograph has been maintained. The other source is the meteorological sub-station of Government of India maintained over here. However, frequent breakdowns in the first source has disrupted the continuity of its data. Hence, for the present work, the data from the second source are used. These consist of:

(a) minimum and maximum daily temperatures,

(b) minimum and maximum daily relative humidities,

and (c) daily rainfalls.

From these the mean daily temperature, mean daily relative humidity and daily rainfall have been compounded and used here.

CHAPTER IV

LOCALITY AND ITS CLIMATE

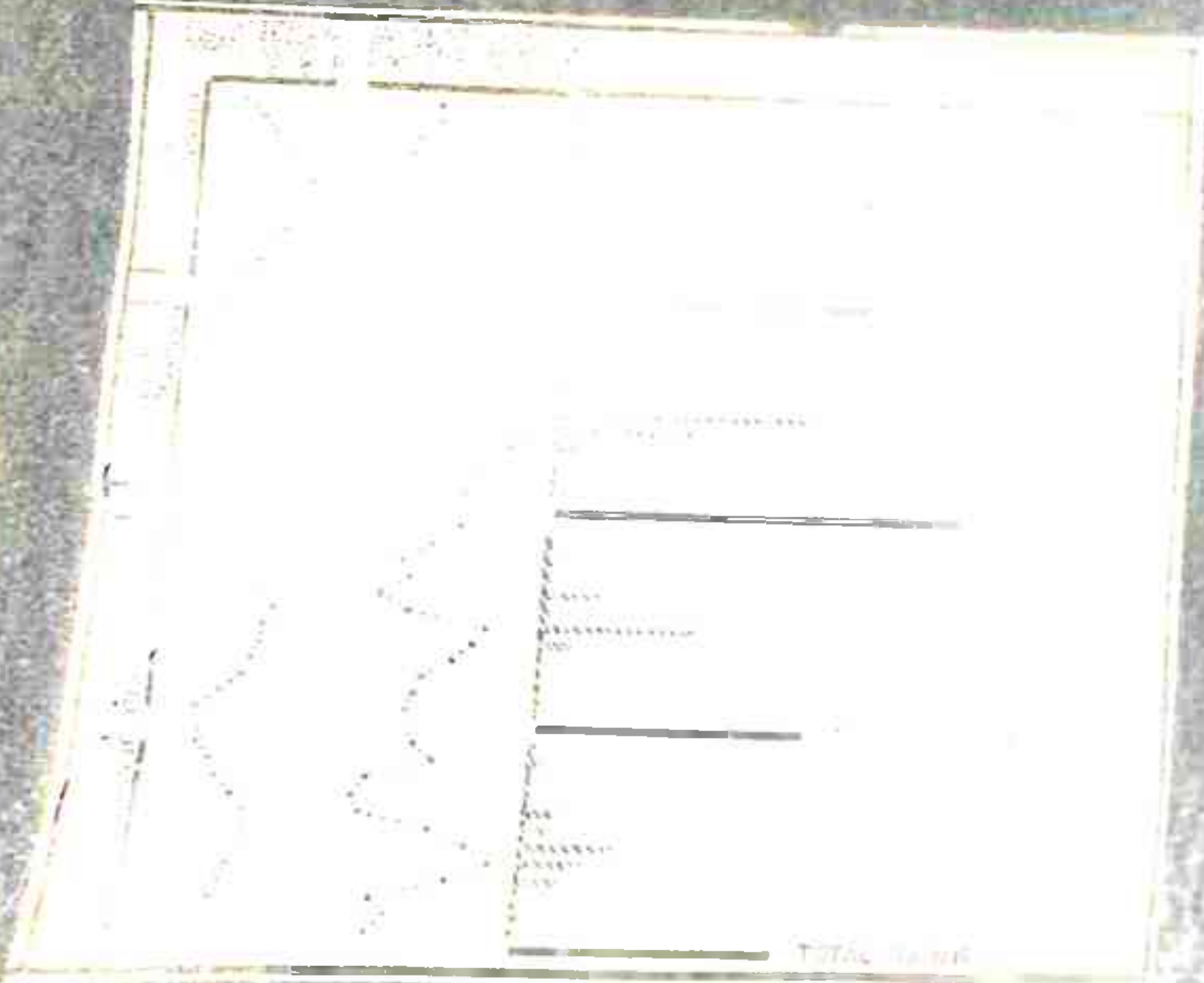
Pilani is 200 kilometres west of Delhi and lies within 28°20'N and 75°35'E and at an elevation of about 330 metres above sea level. The area is semi-arid with gradually stabilising sand dunes. The principal cash crop of this area is "millet" (*Pennisetum typhoideum*) and the endemic vegetation is mostly limited to thorny shrubs and a few trees like *Acacia arabica*, *Prosopis spicigera*, etc. However, the campus of the Institute where traps 'K' and 'B' are situated, owing to ample irrigation facilities, is quite verdant. Whereas the situation of third trap 'E' is by the side of semi-dry grass land.

The annual rainfall is 15" or so, limited mostly to the months of July and August and the temperature varies from -5°C to 47°C. The highest temperature is usually in the month of June and the lowest in January. The daily mean temperature during May and June varies from 30°C to 35°C. Except July, August and September, Pilani is mostly dry, reaching a peak of about 17 to 25% relative humidity in the months of April and May (Table 2 and Fig. 9). Besides low humidities and extreme temperatures there is at least another significant meteorological factor. Being within the semi-arid belt of Rajasthan there are frequent sand-storms during the summer months (April to June) at Pilani. These severely affect the vegetation.

TABLE 2

The monthly average temperatures and relative humidities during the years 1959-1966.

Months	Temp. (°C)	R.H. (%)	Temp. (°C)	R.H. (%)	Temp. (°C)	R.H. (%)	Temp. (°C)	R.H. (%)
	1959		1960		1961		1962	
Jan.	13.40	53.80	13.40	51.86	14.93	50.10	12.92	45.07
Feb.	16.00	40.00	19.78	31.80	18.54	55.00	16.95	46.40
March	23.71	30.65	21.50	43.13	22.80	29.28	22.37	37.62
Apr.	28.80	25.65	27.21	20.58	27.49	25.33	29.71	23.05
May	33.55	27.60	33.20	17.30	32.30	25.64	32.60	21.54
June	35.62	38.85	35.40	32.37	34.57	36.93	35.35	27.20
July	30.85	61.40	31.53	59.00	32.28	58.11	32.52	62.45
Aug.	30.10	69.45	29.93	73.13	29.70	83.20	31.29	64.02
Sep.	28.95	69.60	29.97	56.41	29.42	76.00	28.66	63.30
Oct.	27.10	46.40	25.12	43.20	25.90	44.53	23.61	40.62
Nov.	19.85	48.20	18.95	33.93	18.15	42.90	19.10	42.22
Dec.	15.55	41.25	14.84	40.36	12.50	45.40	14.16	43.22
Av.	25.29	46.07	25.07	41.92	24.88	47.70	24.94	43.06
	1963		1964		1965		1966	
Jan.	12.90	35.90	10.09	48.51	15.25	51.95	15.11	41.08
Feb.	18.46	35.50	16.21	45.86	16.21	42.57	19.08	48.78
Mar.	22.40	28.60	23.95	29.13	21.35	33.29	21.82	28.06
Apr.	27.68	26.45	29.65	19.08	25.19	36.11	27.01	24.61
May	31.56	28.60	30.54	25.60	30.29	27.09	31.33	27.75
June	35.14	33.50	33.99	32.26	34.32	36.00	32.97	49.31
July	34.03	45.50	29.64	70.76	31.01	61.88	32.27	61.56
Aug.	30.03	72.53	29.62	68.09	30.04	58.98	29.40	69.40
Sep.	28.41	55.20	29.65	65.11	28.75	51.33	28.12	56.08
Oct.	26.30	41.60	24.74	52.89	26.41	42.25	26.12	34.48
Nov.	20.90	51.76	17.25	54.43	20.60	40.70	18.14	39.05
Dec.	14.33	45.60	13.86	51.93	13.04	38.59	13.68	34.02
Av.	25.18	41.73	24.10	46.97	24.37	43.40	24.59	42.85



Broadly, the climate of Pilani can be divided into three seasons:

(a) Hot, dry and with sand storm: from the middle of March to the middle of June,

(b) Warm and humid: from the middle of June to the middle of October,

(c) Cold and dry: from the middle of October to the middle of March.

A graphical synopsis of the pertinent meteorological data of the period of trapping is presented in Fig. 9 while all the other relevant data are presented in tabular form (Tables 2 to 6).

The rainfall

It varies from 325 mm to 520 mm. The monsoon runs from 1st week of July till the end of August. There may be some light rains in September coupled with a few occasional showers in winter. During these years 1964 experienced the highest rainfall (520 mm). The rain is more evenly distributed in 1965 where except for January and November, rain falls in all the other months. The highest rainfall on any single day is 46.6 mm on the 8th and the 9th August, 1963; 113.8 mm on the 10th and the 11th July 1964; 160 mm on the 18th and the 19th July, 1965, and 61.6 mm on the 24th and the 25th July, 1966. About 70% rain occurs in the months of July and August. It is interesting to examine the year 1964 from this perspective (Table 3). Both these months

TABLE 3

The monthly rainfalls (mms) and rainy days (in parentheses) during the years 1959-1966

Months	1959	1960	1961	1962
Jan.	2.8 (3)	3.0 (2)	15.8 (3)	1.1 (1)
Feb.	2.8 (2)	0.0 (0)	12.0 (6)	0.4 (1)
Mar.	3.2 (1)	35.0 (6)	0.0 (0)	2.4 (2)
Apr.	0.0 (0)	9.5 (3)	0.0 (0)	2.0 (3)
May	35.0 (2)	2.2 (2)	10.1 (3)	5.8 (5)
June	33.0 (5)	27.9 (4)	46.8 (3)	0.0 (0)
July	62.8 (8)	157.8 (10)	73.2 (5)	277.2 (12)
Aug.	141.8 (8)	180.1 (13)	142.9 (16)	99.5 (11)
Sep.	41.4 (8)	0.4 (1)	72.2 (10)	115.7 (6)
Oct.	27.4 (3)	11.2 (3)	10.3 (1)	0.0 (0)
Nov.	17.4 (1)	0.0 (0)	1.8 (4)	0.0 (0)
Dec.	0.0 (0)	6.8 (1)	1.6 (1)	0.0 (0)
Total	367.6 (39)	433.9 (45)	386.7 (52)	504.1 (41)

Months	1963	1964	1965	1966
Jan.	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
Feb.	0.0 (0)	0.0 (0)	6.2 (1)	13.6 (2)
Mar.	1.4 (3)	1.2 (1)	15.6 (3)	0.0 (0)
Apr.	2.8 (3)	0.0 (0)	7.0 (2)	0.0 (0)
May	12.0 (2)	13.2 (5)	66.0 (4)	35.2 (3)
June	7.5 (5)	0.0 (0)	4.6 (2)	30.3 (6)
July	35.4 (9)	323.4 (12)	198.5 (6)	110.2 (8)
Aug.	236.8 (19)	182.2 (12)	37.3 (7)	75.2 (10)
Sep.	69.3 (5)	0.0 (0)	5.0 (2)	48.0 (5)
Oct.	0.0 (0)	0.0 (0)	1.2 (2)	3.4 (1)
Nov.	11.0 (2)	0.0 (0)	0.0 (0)	8.5 (1)
Dec.	6.4 (2)	0.0 (0)	1.0 (1)	0.0 (0)
Total	382.6 (50)	520.0 (30)	342.4 (30)	324.9 (36)

TABLE 4

Showing deviations in temperatures and relative humidities during four trapping years from the averages.

Months	Temp. °C	1963	1964	1965	1966
Jan.	13.34	-0.44	-3.25	+1.91	+1.77
Feb.	17.49	+0.97	-1.28	-1.22	+1.58
Mar.	22.38	+0.02	+1.57	-1.03	-0.56
Apr.	27.38	+0.30	+2.27	-2.19	-0.37
May	30.93	+0.83	-0.39	-0.64	+0.40
June	34.10	+1.02	-0.11	+0.22	-1.13
July	31.74	+2.29	-2.10	-0.72	+0.53
Aug.	29.77	+0.26	-0.15	+0.26	-0.37
Sep.	28.73	-0.32	+0.91	+0.02	-0.61
Oct.	25.89	+0.41	-1.15	+0.52	+0.22
Nov.	19.23	+1.68	-1.97	+1.38	-1.08
Dec.	13.73	+0.60	+0.13	-0.69	-0.05

Months	R.H. %	1963	1964	1965	1966
Jan.	44.36	- 8.46	+ 4.15	+ 7.59	- 3.28
Feb.	43.18	- 7.68	+ 2.68	- 0.61	+ 5.60
Mar.	29.77	- 1.17	- 0.64	+ 3.52	- 1.71
Apr.	26.56	- 0.11	- 7.78	+ 9.55	- 1.95
May	27.26	+ 1.35	- 1.66	- 0.17	+ 0.49
June	37.76	- 4.26	- 5.50	- 1.76	+11.54
July	59.93	-14.43	+10.83	+ 1.95	+ 1.66
Aug.	67.25	+ 5.28	+ 0.84	- 8.27	+ 2.15
Sep.	56.93	- 1.73	+ 8.18	- 5.60	- 0.85
Oct.	42.81	- 1.21	+10.08	- 0.56	- 8.31
Nov.	46.49	+ 5.27	+ 7.94	- 5.79	- 7.42
Dec.	42.54	+ 3.06	+ 9.39	- 3.95	- 8.50

TABLE 5

The monthly average temperatures, relative humidities, rainfalls (mm) and rainy days (in parentheses) during the years 1963-1966 (the period of operation of the light-traps) with comparable data of four preceding years

Months	Average Temperature (°C)		Relative Humidity (%)		Rainfall (mm) (Rainy days)			
	1959-1962	1963-1966	1959-1962	1963-1966	1959-1962		1963-1966	
Jan.	13.66	13.34	50.21	44.36	5.8	(2.25)	0.0	
Feb.	17.82	17.49	43.30	43.18	3.8	(2.25)	4.9	(0.75)
Mar.	22.59	22.38	35.17	29.77	10.2	(2.25)	4.6	(1.75)
Apr.	28.30	27.38	23.65	26.56	2.9	(1.50)	2.5	(1.25)
May	32.91	30.93	23.02	27.26	13.3	(3.00)	31.6	(3.75)
June	35.24	34.10	33.84	37.76	26.9	(3.00)	10.6	(3.25)
July	31.79	31.74	60.24	59.93	142.8	(8.75)	166.9	(8.75)
Aug.	30.26	29.77	72.45	67.25	141.1	(12.00)	132.5	(12.00)
Sep.	29.25	28.73	66.33	56.93	57.4	(5.75)	30.6	(3.00)
Oct.	25.43	25.89	43.69	42.81	12.2	(1.75)	1.2	(0.75)
Nov.	19.01	19.22	41.81	46.49	4.8	(1.25)	4.9	(0.75)
Dec.	14.26	13.73	42.56	42.54	2.1	(0.50)	1.9	(0.75)
Av.	25.05	24.56	44.69	43.74	35.3	(3.79)	32.5	(3.06)

TABLE 6

Showing deviations in rainfalls (mm) during four trapping years

Months	Average	1963	1964	1965	1966
Jan.	0.0	0.0	0.0	0.0	0.0
Feb.	4.9	- 4.9	- 4.9	+ 1.3	+ 8.7
Mar.	4.6	- 3.2	- 3.4	- 4.6	+ 11.0
Apr.	2.5	+ 0.3	- 2.5	+ 4.5	- 2.5
May	31.6	- 19.6	- 18.4	+ 34.4	+ 3.6
June	10.6	- 3.1	- 10.6	- 6.0	+ 19.7
July	166.9	-131.5	+156.5	+ 31.6	- 56.7
Aug.	132.5	+104.3	+ 47.7	- 95.2	- 56.8
Sep.	30.6	+ 38.7	- 30.6	- 25.6	+ 17.4
Oct.	1.2	- 1.2	- 1.2	± 0.0	+ 2.4
Nov.	4.9	+ 6.1	- 4.9	- 4.9	+ 3.6
Dec.	1.9	+ 4.5	- 1.9	- 0.9	- 1.9

receive rain above their normal share and particularly in July it is almost double of the average.

Table 3 reveals that the amount of rainfall along with rainy days is more during four preceding years than to the trapping. Secondly, except in 1962, the preceding years have the maximum rainfall in August. Thirdly, the rain is more evenly distributed in these years than in the trapping years.

Temperature

The average monthly temperatures for all months except January and September, are higher during 1963 than the combined averages of four years (1963-1966). Henceforth, these years combined average monthly means will be referred to as "normal" temperatures, humidities, etc. The maximum difference 2.29°C is in the month of July. On the contrary, the monthly averages of 1964 are below "normal" for 8 months, going down to -3.25°C in the month of January. Another interesting feature is, except for the month of October, when there are three positive values of departures, in the rest of the months during the four-year period, twice the departures are above "normal" and twice below "normal" (Table 4). Thus on the whole the climate of this period is normal. This can also be easily seen through the climographs (Fig. 10).

Relative humidity

Table 4 shows the departures of the mean monthly relative humidity from the four years means and reveals a

...10. CLIMOGRAPHS ... LANI WITH AVERAGE MONTHLY MEANS OF TEMPERATURES ... HUMIDITY FOR FOUR YEARS 1963 TO 66

Fig. 10

nearly opposite tendency to that which has been observed with regard to temperature. In 1963 the monthly means of 8 months are below "normal" and the highest value of departure is -14.43%, in the month of July. Thus the tendency with relative humidity is opposite to temperature where highest departure is 2.29°C in the same month. The year 1964 again shows the opposite case to what has been observed in the temperature departures, the mean relative humidity is below "normal" during four months. The highest negative value of departure is -7.78% in April and the highest positive value is 10.83% in July. During 1965 the humidity is above "normal" in four months with the highest positive value 9.55% in April and the highest negative value -8.27% in August. In 1966 the humidity is above "normal" in five months and the highest positive value of departure is 11.54% in June and the highest negative value of departure is -8.50% in December.

CHAPTER V

BIOLOGY OF SCARABAEIDAE

(a) General

The family Scarabaeidae is one of the largest families of Coleoptera. According to Leng (1920) the family includes 14 subfamilies. The species under present study belong to 3 subfamilies, namely the Melolonthinae, Rutelinae and Coprinae (vide Chapter III). The following account of the biology deals mainly with reference to these 3 subfamilies.

Published information on the biology of scarabaeids are voluminous because of the world wide distribution and diverse habits of the members of this group. Many scarabaeids have life histories requiring more than one year to complete. Moreover, the same species at different latitudes require different length of time to complete its life cycle. Unlike stored grain or timber beetles, soil inhabiting scarabaeids have a large number of host plants. These host plants may be different from season to season. The methods of oviposition are practically unknown.

Generally the larvae and adults of scarabaeids are either saprophagous or phytophagous. Adults of Coprinae feed on carrion, dung, decaying vegetable matter and fungi (Howden and Ritcher, 1952). Adults of Melolonthinae and Rutelinae devour plant tissues. Some of the Melolonthinae are voraceous eaters of the leaves of shrubs. In Malaya adults of Apogonia cribricollis attack the leaves of cacao (Lever, 1953) and in Sudan, Schizonycha feeds on the leaves of dolichos (Pollard,1956). Many species of Anomala, however, feed little or not at all in their adult stages. The food of the Coprinae larvae is provided by the adults. The adults of Copris form bolls and pack them in underground chambers. Most other genera pack tubular burrows with food materials for their larvae. Melolonthinae and Rutelinae larvae mostly prefer to feed on the roots of living plants, while there are many who feed on humus, decaying organic matter, etc. Some larvae of Schizonycha have been reported to feed on pea nuts and roots of sorghum (Pollard, 1956). Generally Anomalines feed on roots of living plants. Larvae of Anomala vetula injure roots of turf in South Africa (Bredford, 1948). Grubs of some Anomala and Adoretus feed on rotten vegetations (Mitchell,1946). Ravages caused to the turf in United States by the larvae of Popillia japonica (Ruteline) is well-known. But there are a few scarabaeids which are predaceous, such as Aphodius porcus, some species of Trox etc.

It is generally believed that all scarabaeids without exception, have three larval instars. However, Floyd Ellertson and Ritcher (1956), while studying the biology of several species of Plecoma at Oregon, have found that larvae of this peculiar genus may moult from 7 to 11 times with one moult occurring each year.

Usually scarabaeid larvae construct a cell to pupate. Some dung feeders (Aphodius) pupate in cell which has the old dung mass but most species pupate in the soil. The wood feeding forms prepare the pupal case from wood fragments accumulated in the tree cavities. With regard to the time of pupation, lots of variations are reported. In the genus *Anomala*, *Anomala nigropicta* and *Anomala binotata* pupate in the fall, overwinter as adults and appear in flight early in the next spring. In the same locality *Anomala innuba* overwinters as adults. Larva pupates in the spring and does not appear in the flight until early June (Ritcher, 1943). Similarly most species of *Serica* common to Eastern United States pupate in the fall, overwinter in the soil as adults, and fly in the early spring. In California, in contrast, it has been found that most species of *Serica* overwinter as full grown larvae and pupate in the late winter and early spring (Ritcher, 1949). Ritcher (1958) has presented a summary of the length of pupation period of large number of scarabaeids. This period varies from as little as two weeks to fourteen weeks, depending upon species. From the laboratory studies on the biology of *Melolontha melolontha*, it has been determined that the pupal period of this insect varies with temperature, being 3 to 4 months at 12°C and 4 to 5 weeks at 20 to 25°C (Vogel and Ilic, 1953).

The length of life cycle of scarabaeids varies with the climate, being the longest in more temperate regions and the shortest in the tropical areas. However, life cycles may be comparatively long in regions having a hot dry season (since the larvae may aestivate till monsoon breaks up, Moutia 1940). Life cycles of Melolonthines and Rutelines tend to be rather long in temperate climate being spread over 2 to 3 years. The same species may have a longer life cycle in a northern latitude than in a southern one. *Anomala orientalis* has one year life cycle in the Southern United States but a two year life cycle in Connecticut. Gressitt (1953) studied *Oryctes rhinoceros* in the Palan Island where there is no discernible seasonal variation. He found that given favourable condition more than three generations may develop in one year.

The mating behaviour is very variable. Interspecific mating is the general rule. While many Geotrupinae mate in burrows in the soil, Melolonthines (*Serica* etc.) mate at night while the female continues feeding on foliage. Members of some genera mate on the surface of the soil with many males competing for single female. Some members of Melolonthinae such as *Hoplia* mate on flowers in day time. It is interesting to note that *Geotrupes splendidus* mates in the fall, but the eggs are not laid until the following spring.

However, all these information are about non-Indian scarabaeids. Information regarding the biology of Indian scarabaeids is inadequate. In fact "the details of the life history of a few Indian species has been observed" (Lefroy, 1909).

(b) Biology of Indian scarabaeids

Here a brief review of the biology of Indian scarabaeids based mainly on Lefroy (1909), Stebbing (1914) and Beeson (1941) is presented.

Melolonthinae

These are mostly night-fliers feeding on trees and foliage. Eggs are laid in the soil. The larval stage is passed in humus or in the soil and show some amount of seasonal vertical movement, descending to the deeper levels in hot and dry weather and ascending within a few inches of the surface in wet and cool weather. *Autoserica insanabilis* is a defoliator of teak (*Tecrona grandis*). The larva of this species occurs in the soil containing roots of shrubs. *Holotrichia seticollis* is known to swarm at the beginning of monsoon and defoliates various trees such as *Cassia* and *Lagerstroemia* (Beeson, 1941). *Apogonia* usually feed in swarms at night. *A. ferruginea* defoliates *Bombax*, *Ficus* and other trees in June and July. *Schizonycha ruficollis* is a general defoliator at the beginning of rains when the beetle lives for over one month and the egg batches within seven to ten days.

The melolonthine grubs frequently damage the seed beds by destroying rootlets or removing of the bark of the tap root. It is very likely that many species are polyphagous though the details of their host plants are not well-known. In the sub-tropical plains the life cycle is normally annual with a larval period of 8 to 10 months but in the mountainous places above 6000 ft. the cycle frequently lasts for about two years.

Rutelinae

The rutelines include both day and night fliers. While some species fly exclusively in day time (*Popillia* and *Mimela*) others such as *Anomala* comprises both day flying and night flying species. The adults are mostly defoliators while the larvae feed on the roots of grasses and other cereals. The adults of *Adoretus lasiopygus* feed on *Bombax malabaricum* and *Cassia fistula* among other trees, the feeding method of the adult on leaves is very characteristic (Beeson, 1941) and helps in recognising the pest.

The life histories of only a few species are known. Eggs of *Anomala varians* are laid in the soil in the early rains. The larvae live on the roots of cereals and rest in the soil from September to March. In March, April or May these pupate and emerge after about 10 days (Lefroy, 1909). The whole life cycle occupies one year. According to Beeson (1941) the larvae of *Anomala ruficapilla* occur in soil with roots of grasses. The only other species whose life history is well worked out is *Anomala polita* - a general defoliator of various trees including *Cassia* and *Lagerstroemia* (Beeson, 1941). The emergence of this species from the soil is determined by the local showers. The life cycle is annual. Generally the rutelines are defoliators as adults and destroyers of the root system of plants as larvae.

Coprinae

These are saprophagus, feeding either on dung or dead insects. Many species of *Catharsius* which are common, fly at night and come freely to lights in the rains (Lefroy, 1909). The biology of most coprines are not known. Onthophagus longicornis lays one egg inside each boll of dung. These bolls are burried 3 to 5 inches below the surface under the cow-dung. The larva feeds on the boll, the larval life lasting for 21 days and the total time from egg to imago is about 5 weeks. Emergence takes place in May/June and in other seasons the beetles are found in the soil. The life history of Oniticellus cinctus is broadly similar to that of Onthophagus longicornis. The life history of Catharsius pithecus and other common coprines are not known. Catharsius molossus is known to fly at night and come freely to lights in rains. Coprines are scavengers and thus play an important role in the ecology of forest.

Generally there are three instars in most scarabaeids. The length of life cycle varies from as short as 3 months to 4 to 5 years. Those having one year life cycle, there may be moults during summer and autumn of the year, the egg is hatched. In species with two years life cycle, the two moults prior to pupation occur the same season the egg is hatched. In species with three or more years life cycle the larvae undergo only one moult per year. The pupation behaviour of scarabaeids, such as the location of pupae, time necessary to complete pupation etc., is very specific. According to Ritcher (1940) several species of Indian Phyllophaga, though closely related taxonomically, are distinct entities biologically. This is an important fact which is not taken notice of by many economic entomologists. For example, in America

Anomala nigropicta pupates in the fall, overwinters as adult and appears in the flight early next spring. In the same locality *A. innuba* overwinters as mature larva and does not appear in the flight until early June (Ritcher, 1958).

The chafer larvae are very sensitive to temperature and moisture changes in their microhabitat. The vertical movement of the larvae in the soil is largely determined by moisture and temperature gradients. The time and rate of the downward migration of grubs in fall varies with the amount of early precipitation, soil moisture and soil temperature.

The duration of the life cycle depends mainly on temperatures. Usually the cycle is long in cold areas and short in warm areas. In some areas with dry and hot seasons the life cycle may be longer because the larvae may aestivate till the rainy season sets in. For instance, in India the life cycle of *Leucopholis coneophora* - a melolonthine, is one year duration (Sekhar, 1959) but in Europe the life cycle of *Melolontha hippocastani* is spread over 5 years. Similarly the life cycle of *Melolontha melolontha* depends upon the latitude. The knowledge of the life cycles of Indian Coprinae and Troginae is inadequate.

CHAPTER VI

OBSERVATIONS AND THEIR ANALYSIS

(A) Survey of the captures

(B) Analysis

(A) Survey of the captures

Yearly distribution

The total number of scarabaeids belonging to these 8 species captured during these 4 years of study, through 3 light traps is 3,03,790. Table 7 summarises the total captures of each species and their relative abundance. Obviously, species *A. lasiopygus* is the most abundant (66.53%) and species *A. ruficapilla* is the least abundant (0.36%). Table 8 gives the yearly captures of all the species trapwise. It is clear from this table that *A. lasiopygus* constitutes two-third (2,02,118) of the total catch. The least abundant species among these is *A. ruficapilla* of which only 1087 individuals were trapped during 4 years. Among the four years of the captures the highest catch (1,38,441) is during 1964, this constitutes 45.5% of the total catch. The captures during other years are 20.9% (1963), 16.4%(1965) and 17.1% (1966). Four species namely *A. lasiopygus*, *S. ruficollis*, *C. pithecus* and *A. ruficapilla* show the highest captures during 1964. Three species namely, *A. compressus*, *A. ferruginea* and *H. seticollis* show the highest captures during 1965 whereas the remaining species has the highest captures during 1966.

TABLE 7

The total captures of each species and their relative abundance

Species	Total No. captured	Relative %
A. lasiopygus	202118	66.53
S. ruficollis	34314	11.29
S. pithecus	26379	8.68
A. compressus	15953	5.25
A. ferruginea	9576	3.15
H. seticollis	7471	2.46
A. insanabilis	6892	2.27
A. ruficapilla	1087	0.36
Total	303790	

TABLE 8

Yearly captures of all the species trap-wise

Species		1963	1964	1965	1966	Total
A. lasiopygus	B	6612	12057	2861	3556	25086
	E	13568	21325	5574	10897	51364
	K	28754	73968	11168	11778	125668
S. ruficollis	B	1697	6632	4809	4099	17237
	E	563	2292	2703	2452	8010
	K	1200	3087	3085	1695	9067
C. pithecus	B	357	609	530	1390	2886
	E	978	1129	1384	2165	5656
	K	2198	7484	3522	4633	17837
A. compressus	B	512	477	812	891	2692
	E	182	250	569	911	1912
	K	1802	2848	4198	2501	11349
A. ferruginea	B	430	455	1903	570	3358
	E	810	173	296	371	1650
	K	1115	1294	1124	1035	4568
H. seticollis	B	415	632	907	295	2249
	E	286	260	818	224	1588
	K	544	1466	1320	304	3634
A. insanabilis	B	292	390	599	424	1704
	E	133	119	151	245	648
	K	955	825	1301	1458	4539
A. ruficapilla	B	103	298	75	18	494
	E	43	160	29	9	241
	K	72	211	56	13	352
Total	B	10418	21550	12496	11243	55565
	E	16563	25708	11524	17274	71069
	K	36640	91183	25774	23417	177156
Grand Total		63621	138441	49794	51934	303790

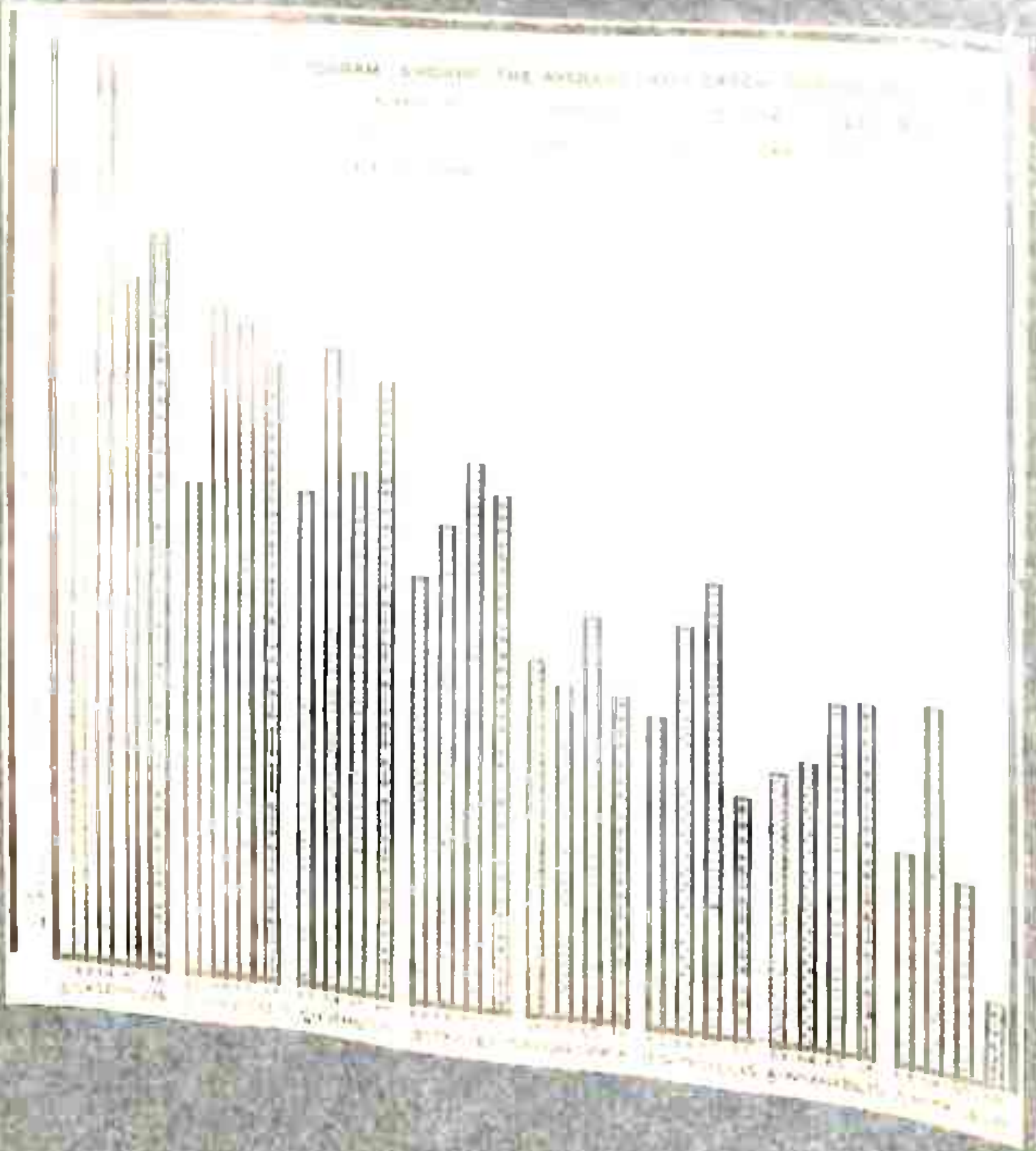


Fig. 11

Monthly distribution

It can be seen from Table 9 that two species namely, A. insanabilis and A. ferruginea are active from March to October. Three species namely, A. lasiopygus, C. pithecus and H. seticollis are active from May to October whereas, S. ruficollis, A. compressus and A. ruficapilla are active from May to September, April to August and May to August respectively.

Except A. lasiopygus, which is always the most abundant in the month of September, and A. compresses which is the most abundant in the month of May, the rest of all the six species are the most abundant in the month of July. Out of these six species, A. ruficapilla, H. seticollis and S. ruficollis have 85%, 82% and 80% catches in the month of July only. C. pithecus shows 50% catch in July. A. insanabilis and A. ferruginea, although more abundant during July but are well distributed during other months also. A. lasiopygus has 62% catch during September whereas A. compressus has 46% catch during May. The percentage catch in various months is 42.90%, 30.81%, 19.04%, 3.06%, 2.60%, 1.22%, 0.30% and 0.06% during September, August, July, May, June, April, October and March respectively.

A. insanabilis and A. ferruginea have similar distribution, both the species appear in the third week of March between 15th to 25th each year, and disappear from captures in October again between 15th to 25th. The highest number of beetles recorded in single night of A. insanabilis is 80, on

TABLE 9

Total monthly captures of each species during four years (1963 to 1966)

Year	March	April	May	June	July	Aug.	Sep.	Oct.
				A. insanabilis				
1963	26	252	57	246	240	376	152	31
1964	16	160	84	66	363	394	227	24
1965	29	423	202	483	554	191	110	59
1966	44	235	82	443	727	411	170	15
Total	115	1070	425	1238	1884	1372	659	129
				A. ferruginea				
1963	12	224	43	29	1066	682	295	4
1964	3	345	354	19	1070	99	26	6
1965	35	319	234	21	2547	136	26	5
1966	31	213	76	325	789	521	17	4
Total	81	1101	707	394	5472	1438	364	19
				A. lasiopygus				
1963	-	-	-	-	19	6104	42575	236
1964	-	3	22	22	312	48670	58160	161
1965	-	10	154	90	405	8459	10466	19
1966	-	3	20	67	116	10981	15027	17
Total	-	16	196	179	852	74214	126228	433
				A. compressus				
1963	-	449	1094	426	445	82	-	-
1964	-	358	1704	296	1161	54	2	-
1965	-	472	2925	1471	663	43	5	-
1966	-	299	1607	1753	582	62	-	-
Total	-	1578	7330	3946	2851	241	7	-

(Contd.)

Table 9 (Contd.)

Year	March	April	May	June	July	Aug.	Sep.	Oct.
				S. ruficollis				
1963	-	-	123	66	1578	1685	8	-
1964	-	-	25	28	10486	1460	12	-
1965	-	-	146	135	9654	650	12	-
1966	-	-	85	438	4894	2791	38	-
Total	-	-	379	667	26612	6586	70	-
				C. pithecus				
1963	-	-	-	-	542	2219	732	40
1964	-	-	-	2	6329	1559	1252	80
1965	-	-	129	77	3752	1302	152	24
1966	-	-	34	853	2478	4117	669	37
Total	-	-	163	932	13101	9197	2807	181
				H. seticollis				
1963	-	-	-	3	1036	124	58	24
1964	-	-	3	7	2201	98	29	20
1965	-	-	29	164	2644	142	39	27
1966	-	-	8	342	275	133	48	15
Total	-	-	40	516	6156	497	174	86
				A. ruficapilla				
1963	-	-	2	6	192	18	-	-
1964	-	-	1	4	649	15	-	-
1965	-	-	60	19	80	1	-	-
1966	-	-	8	28	4	-	-	-
Total	-	-	71	57	925	34	-	-
Total of all species	196	3765	9311	7929	57853	93579	130309	848

21-22/7/1965 and 21-22/6/1966 and that of *A. ferruginea* is 720, on 21-22/7/1965.

A. lasiopygus appears in captures in May but its regular activity is always in the month of July after several monsoon showers when the day temperatures goes considerably down and nights more humid. The period between its first appearance in the traps and regular activity is found constant during all the years. From the middle of August to the middle of September the species has always reckoned in thousands. The highest number of beetles in single night is 13208, on 29-30/8/1964.

A. compressus appears in the beginning of second week of April and is active upto the end of August. The maximum number of individuals (517) in single night is on 21-22/5/1965.

S. ruficollis appears in the trap captures in the second week of May till September. The maximum catch (2152) is on 21-22/7/1964. *C. pithecus* appears in the third week of May and active upto the end of third week of October. The highest catch 1368 is on 12-13/7/1964. *H. seticollis* appears in the second week of May and remains active till the end of October. This species has the peak activity during July and August. The highest catch (384) is on 9-10/7/1964.

A. ruficapilla is the least abundant out of all. It appears in the captures in the last week of May or in the first week of June and disappears in the captures in the last week of July or in the first week of August. The highest captures 152 is on 11-12/7/1964.

TABLE 10

Trap-wise catches of Autoserica insanabilis based on 5 day running means for March to October 1963-1966

Dates	1963			1964			1965			1966		
	B	E	K	B	E	K	B	E	K	B	E	K
March												
1-5	-	-	-	-	-	-	-	-	-	-	-	-
6-10	-	-	-	-	-	-	-	-	-	-	-	-
11-15	-	-	-	-	-	-	-	-	-	0.4	-	-
16-20	0.4	-	0.6	-	-	-	-	-	-	0.6	0.2	0.6
21-25	0.4	0.4	1.6	0.4	-	0.4	-	-	0.2	3.0	0.8	1.0
26-31	-	-	1.5	0.7	0.3	1.0	0.8	0.2	3.7	0.5	-	1.3
Total	0.8	0.4	3.7	1.1	0.3	1.4	0.8	0.2	3.9	4.5	1.0	2.9
April												
1-5	2.2	-	1.4	0.6	-	2.4	3.8	-	4.8	1.2	-	0.4
6-10	0.4	-	2.8	2.8	0.2	4.0	1.8	0.4	7.4	1.2	0.6	4.2
11-15	3.4	0.2	6.6	2.6	-	10.8	3.2	0.2	3.8	3.2	0.6	11.4
16-20	3.2	-	6.4	1.0	-	2.8	1.6	0.2	13.0	1.0	0.2	7.0
21-25	2.4	-	8.2	0.6	-	0.4	7.2	-	15.0	2.2	0.8	7.0
26-30	3.0	0.2	10.0	1.8	0.2	1.8	7.8	0.2	14.2	1.0	-	5.0
Total	14.6	0.4	35.4	9.4	0.4	22.2	25.4	1.0	58.2	9.8	2.2	35.0
May												
1-5	0.2	-	4.2	1.4	0.6	5.0	7.6	0.6	6.0	0.2	-	1.0
6-10	0.2	-	2.0	1.2	0.6	3.2	2.0	0.4	2.4	0.4	0.2	3.4
11-15	-	-	1.0	0.2	0.2	1.4	2.0	-	1.0	0.6	-	3.6
16-20	0.4	0.2	2.6	0.4	-	0.4	1.4	1.2	5.6	0.6	-	2.4
21-25	-	-	-	-	0.4	1.2	1.6	0.2	6.2	-	0.2	2.4
26-31	-	-	0.5	-	-	0.5	0.5	0.2	0.5	0.2	-	0.6
Total	0.8	0.2	10.3	3.2	1.8	11.7	15.3	2.6	21.7	2.0	0.4	13.4
June												
1-5	-	-	1.8	0.2	-	0.2	1.0	0.2	0.8	0.6	-	1.4
6-10	0.2	-	7.0	-	-	2.8	1.4	-	1.0	-	0.6	6.2
11-15	1.2	-	9.6	-	-	2.0	1.0	0.2	3.6	0.4	-	13.4
16-20	0.8	-	11.2	-	-	2.4	4.6	0.2	22.2	0.2	0.8	30.0
21-25	1.4	-	7.0	1.0	-	1.6	7.6	-	36.6	0.4	0.4	22.4
26-30	1.4	-	7.6	0.6	-	2.4	3.2	-	13.0	0.2	1.0	10.6
Total	5.0	-	44.2	1.8	-	11.4	18.8	0.6	77.2	1.8	2.8	84.0

(Contd.)

Table 10 (Contd.)

Dates	1963 B	1963 E	1963 K	1964 B	1964 E	1964 K	1965 B	1965 E	1965 K	1966 B	1966 E	1966 K
July												
1-5	0.6	0.4	9.8	3.0	0.2	2.2	8.6	1.8	7.4	1.6	2.6	14.6
6-10	1.2	-	2.4	7.2	1.6	2.8	0.6	0.4	2.6	6.0	3.2	32.0
11-15	-	-	-	25.6	-	-	6.0	1.6	9.0	2.8	2.8	20.0
16-20	0.4	-	2.4	1.4	8.0	2.2	7.0	2.6	21.0	3.2	1.4	8.6
21-25	1.6	-	-	0.4	1.0	4.8	4.2	5.6	9.2	6.4	8.8	21.6
26-31	7.3	1.6	15.3	2.8	1.3	6.0	6.5	2.0	10.8	2.3	2.2	3.7
Total	11.1	2.0	29.9	40.4	12.1	18.0	32.9	14.0	60.0	22.3	21.0	100.5
August												
1-5	1.0	1.2	14.0	3.8	2.2	23.2	1.6	1.6	4.0	2.6	4.6	4.2
6-10	3.6	4.0	4.2	3.0	1.6	16.0	1.2	0.2	4.4	4.0	6.4	3.6
11-15	3.6	0.4	8.4	1.6	1.2	5.6	3.4	1.2	3.2	4.0	6.4	9.6
16-20	6.0	1.4	9.6	-	-	4.4	1.0	1.6	1.8	2.4	7.2	11.2
21-25	1.6	-	8.4	0.8	0.2	5.6	1.2	0.4	1.8	1.0	4.0	4.0
26-31	3.2	-	3.3	1.2	0.8	6.0	2.7	0.8	4.0	0.3	3.0	2.5
Total	19.0	7.0	47.9	10.4	6.0	60.8	11.1	5.8	19.8	14.3	31.6	35.1
Septr.												
1-5	-	-	1.8	3.6	-	20.0	0.6	1.2	0.6	1.6	1.6	3.2
6-10	0.2	-	3.2	2.0	-	8.0	0.6	0.2	-	0.2	0.6	6.2
11-15	1.6	-	9.6	1.4	0.6	0.8	2.6	0.6	0.4	2.0	4.4	5.2
16-20	1.2	-	2.2	0.2	1.2	0.6	1.8	0.6	2.6	1.2	2.0	3.0
21-25	2.4	0.2	6.2	0.2	0.2	2.2	0.2	0.2	2.8	0.2	0.4	0.8
26-30	0.2	-	1.6	1.2	0.2	3.0	2.8	1.4	2.8	0.8	0.2	0.4
Total	5.6	0.2	24.6	8.6	2.2	34.6	8.6	4.2	9.2	6.0	9.2	18.8
Oct.												
1-5	0.2	-	1.2	1.0	0.4	0.4	3.2	1.2	2.0	0.6	0.2	0.4
6-10	0.2	-	0.6	1.0	-	-	0.8	-	0.6	0.4	0.2	0.4
11-15	0.8	-	1.8	0.6	0.2	1.0	0.8	-	0.8	0.2	-	0.2
16-20	-	-	1.2	-	-	0.2	1.0	-	-	0.2	-	0.2
21-25	-	-	0.2	-	-	-	0.4	0.2	0.6	-	-	-
26-31	-	-	-	-	-	-	0.2	-	-	-	-	-
Total	1.2	-	5.0	2.6	0.6	1.6	6.4	1.4	4.0	1.4	0.4	1.2

TABLE 11

Trap-wise catches of *Apogonia ferruginea* based on 5 day running means for March to October 1963-1966

Dates	1963			1964			1965			1966		
	B	E	K	B	E	K	B	E	K	B	E	K
March												
1-5	-	-	-	-	-	-	-	-	-	-	-	-
6-10	-	-	0.2	-	-	-	-	-	-	-	-	-
11-15	-	-	-	-	-	-	-	-	0.2	-	0.2	-
16-20	-	-	-	-	-	-	0.2	-	0.4	-	-	1.4
21-25	-	-	1.0	-	-	0.2	-	-	0.8	0.2	0.4	1.8
26-31	-	-	1.0	-	-	0.3	-	-	4.5	-	-	1.8
Total	-	-	2.2	-	-	0.5	0.2	-	5.9	0.2	0.6	5.0
April												
1-5	0.2	0.2	1.6	0.8	-	0.8	0.2	-	10.0	0.4	-	1.6
6-10	0.6	-	3.4	2.0	0.4	3.4	0.4	-	13.0	1.2	0.6	2.8
11-15	1.0	0.2	7.4	4.4	1.0	18.4	0.6	0.2	4.0	1.0	1.4	6.0
16-20	-	-	4.0	3.0	0.8	10.4	1.0	0.2	4.0	1.2	2.0	4.8
21-25	1.4	0.2	14.4	0.6	1.2	13.4	2.4	2.2	10.6	2.8	2.8	9.8
26-30	0.4	0.6	9.2	1.2	0.2	7.0	2.2	1.8	11.0	1.0	0.4	2.8
Total	3.6	1.2	40.0	12.0	3.6	53.4	6.8	4.4	52.6	7.6	7.2	27.8
May												
1-5	0.8	0.2	2.4	1.6	1.8	29.4	1.4	1.2	18.0	0.2	0.6	2.6
6-10	-	0.2	1.8	2.0	0.8	12.8	1.2	0.4	6.0	0.8	0.4	2.4
11-15	-	-	0.8	2.4	0.6	9.6	0.6	0.8	5.8	0.2	-	0.6
16-20	-	-	1.2	0.2	0.2	5.2	-	0.4	2.0	0.4	0.4	1.6
21-25	-	0.2	-	-	-	1.8	-	-	3.0	-	0.2	2.6
26-31	-	-	0.8	-	-	2.0	0.5	1.0	3.5	0.3	-	1.5
Total	0.8	0.6	7.0	6.2	3.4	60.8	3.7	3.8	38.3	1.9	1.6	11.3
June												
1-5	-	-	0.4	-	-	1.6	-	0.2	1.0	-	-	0.4
6-10	-	-	-	0.2	-	0.2	0.2	0.2	0.8	-	0.2	1.0
11-15	0.4	0.2	0.2	0.2	-	0.6	-	0.2	0.4	0.4	-	1.6
16-20	0.8	-	0.4	-	-	0.4	-	-	0.6	2.0	4.4	10.2
21-25	0.2	0.2	0.4	-	-	-	-	-	0.4	7.0	2.0	21.6
26-30	1.0	0.6	1.0	0.2	0.2	0.2	-	-	0.2	2.2	1.8	9.8
Total	2.4	1.0	2.4	0.6	0.2	3.0	0.2	0.6	3.4	12.0	8.4	44.6

(Contd.)

Table 11 (Contd.)

Dates	1963 B	1963 E	1963 K	1964 B	1964 E	1964 K	1965 B	1965 E	1965 K	1966 B	1966 E	1966 K
July												
1-5	2.0	-	4.6	-	4.0	1.0	0.6	1.8	1.0	8.4	2.4	14.4
6-10	0.2	0.2	3.8	33.6	4.0	29.6	-	0.2	4.2	14.4	9.6	19.2
11-15	0.8	0.6	3.2	22.8	7.2	36.0	2.0	-	2.8	1.4	0.8	10.0
16-20	-	74.6	90.4	12.8	6.2	30.8	113.8	17.8	29.4	0.8	-	1.6
21-25	4.8	0.8	6.2	3.2	1.0	12.2	205.8	10.6	52.8	11.4	15.2	18.8
26-31	9.7	2.8	5.0	1.2	2.2	4.7	29.3	9.5	16.7	10.2	5.0	9.3
Total	17.5	79.0	113.2	73.6	24.6	114.3	351.5	39.9	106.9	46.6	33.0	73.3
Aug.												
1-5	11.6	8.4	8.6	1.4	1.0	4.0	4.6	2.6	4.6	18.4	6.0	12.8
6-10	7.6	12.0	5.0	1.0	2.0	5.6	0.2	-	0.6	21.6	9.6	15.2
11-15	13.4	16.4	16.2	0.8	0.2	2.2	0.2	0.2	0.2	2.4	5.2	3.2
16-20	8.8	7.8	10.6	-	-	-	0.2	0.2	0.4	0.2	0.4	7.6
21-25	1.8	2.0	-	-	0.2	1.0	2.4	0.6	0.8	0.2	0.2	0.6
26-31	0.5	0.3	4.3	0.3	-	-	2.0	1.7	3.3	0.2	-	0.3
Total	43.7	46.9	44.7	3.5	3.4	12.8	10.6	5.3	9.9	43.0	21.4	39.7
Sept.												
1-5	-	1.0	-	0.4	-	-	0.8	-	1.6	-	-	-
6-10	0.2	10.2	1.4	0.2	-	3.2	-	-	-	-	0.4	0.4
11-15	9.2	18.0	2.6	-	-	-	0.2	0.2	0.4	-	-	0.2
16-20	5.4	2.8	6.6	-	-	-	-	-	-	0.2	0.4	0.8
21-25	-	-	-	0.2	-	0.8	-	0.2	0.8	-	-	-
26-30	0.8	0.8	-	-	-	0.3	-	-	0.8	-	-	0.8
Total	15.6	32.8	10.6	0.8	-	4.3	1.0	0.4	3.6	0.2	0.8	2.2
Oct.												
1-5	-	-	0.2	-	-	0.8	-	-	0.2	0.2	-	0.4
6-10	0.2	-	0.2	-	-	0.2	-	-	-	-	-	-
11-15	-	-	-	-	-	0.2	-	-	-	-	-	0.2
16-20	0.2	-	-	-	-	-	-	0.2	0.2	-	-	-
21-25	-	-	-	-	-	-	-	-	0.4	-	-	-
26-31	-	-	-	-	-	-	-	-	-	-	-	-
Total	0.4	-	0.4	-	-	1.2	-	0.2	0.8	0.2	-	0.6

TABLE 12

Trap-wise catches of *Adoretus lasiopygus* based on 5 day running means for May to October 1963-1966.

Dates	1963			1964			1965			1966		
	B	E	K	B	E	K	B	E	K	B	E	K
May												
1-5	-	-	-	-	-	0.2	-	-	0.4	-	-	-
6-10	-	-	-	-	-	0.2	-	-	3.2	-	-	0.2
11-15	-	-	-	0.2	0.2	2.8	-	-	0.2	1.4	-	1.6
16-20	-	-	-	-	-	-	-	-	2.4	0.2	-	0.2
21-25	-	-	-	-	-	-	0.8	-	21.6	0.4	-	-
26-31	-	-	-	0.2	-	0.5	-	0.3	1.5	-	-	-
Total	-	-	-	0.4	0.2	3.8	0.8	0.3	29.3	2.0	-	2.0
June												
1-5	-	-	-	-	-	-	1.0	0.2	1.8	-	-	0.2
6-10	-	-	-	-	-	0.8	0.2	0.2	0.8	0.4	-	-
11-15	-	-	-	0.4	-	0.4	-	0.2	0.8	0.6	-	2.0
16-20	-	-	-	-	-	0.2	1.8	-	1.2	1.6	0.2	1.8
21-25	-	-	-	-	-	0.6	1.2	-	1.6	0.2	2.4	2.4
26-30	-	-	-	1.0	-	1.0	3.8	0.2	3.0	0.4	0.2	1.0
Total	-	-	-	1.4	-	3.0	8.0	0.8	9.2	3.2	2.8	7.4
July												
1-5	-	-	0.4	0.6	-	0.6	4.6	1.8	2.2	0.6	-	0.2
6-10	-	-	-	-	1.2	4.2	1.0	0.8	4.0	-	1.0	3.0
11-15	0.6	-	-	-	1.2	4.2	1.0	0.8	8.0	-	1.0	2.2
16-20	-	-	-	-	-	12.0	4.8	1.6	4.0	0.2	0.2	3.4
21-25	-	-	-	0.6	-	0.2	6.2	0.8	18.6	1.0	1.8	2.6
26-31	0.3	2.0	-	2.0	8.0	21.3	4.5	2.3	10.5	1.2	1.2	2.7
Total	0.9	2.0	0.4	3.2	10.4	42.5	22.1	8.1	47.3	3.0	5.2	14.1

Table 12 (Contd.)

Dates	1963			1964			
	B	E	K	B	E	K	B
Aug.							
1-5	-	1.0	0.6	8.0	36.6	170.8	5.[illegible]
6-10	0.6	-	8.2	4.2	11.4	65.4	5.[illegible]
11-15	1.4	2.4	109.6	45.8	59.8	217.6	4.[illegible]
16-20	13.0	5.4	106.8	66.4	102.4	407.2	11.4
21-25	36.0	9.2	298.2	72.8	105.6	661.6	14.[illegible]
26-31	167.0	183.3	368.7	312.0	653.3	5430.0	69.8
Total	218.0	201.3	792.1	509.2	969.1	6952.6	110.[illegible]
Sept.							
1-5	328.0	258.0	713.6	384.0	880.4	786.8	215.8
6-10	380.0	833.0	1467.0	148.4	256.4	1300.8	115.[illegible]
11-15	237.0	1030.0	1956.0	81.0	125.4	248.0	52.0
16-20	85.0	216.0	618.0	12.8	57.0	114.4	21.8
21-25	23.0	89.2	199.4	6.6	10.0	50.0	8.[illegible]
26-30	10.8	30.8	42.2	1.4	17.4	131.2	3.0
Total	1063.8	2457.0	4996.2	634.2	1346.6	2631.2	416.0
Oct.							
1-5	5.0	10.4	11.6	0.2	4.8	19.2	0.6
6-10	1.0	5.2	8.0	-	1.4	4.6	-
11-15	0.2	0.4	4.0	-	0.4	1.2	-
16-20	-	0.4	0.8	-	-	0.2	-
21-25	-	-	0.2	-	-	-	-
26-31	-	-	-	-	-	-	-
Total	6.2	16.4	24.6	0.2	6.6	25.2	0.6

TABLE 13

Trap-wise catches of *Adoretus compressus* based on 5 day running means for April to August 1963-1966

Dates	1963			1964			1965			1966		
	B	E	K	B	E	K	B	E	K	B	E	K
April												
1-5	-	-	-	-	-	-	-	-	-	-	-	-
6-10	-	-	-	1.2	0.2	1.0	0.2	-	0.2	0.2	-	0.2
11-15	2.6	-	4.6	2.0	0.6	16.2	0.2	-	1.2	0.4	-	2.6
16-20	4.0	0.2	13.8	1.8	0.2	13.6	0.4	0.2	7.8	2.0	0.6	3.8
21-25	6.2	1.2	25.4	1.6	1.0	16.6	2.4	0.8	28.8	11.2	2.0	15.6
26-30	5.0	0.2	27.2	1.8	0.8	13.0	1.8	0.6	49.8	5.2	2.0	14.0
Total	17.8	1.6	70.4	8.4	2.8	60.4	5.0	1.6	87.8	19.0	4.6	36.2
May												
1-5	3.2	0.6	12.4	8.6	4.8	40.4	8.6	3.2	56.8	3.6	2.8	5.6
6-10	2.2	1.0	15.6	9.8	2.0	33.2	3.4	1.2	30.4	12.6	8.6	22.2
11-15	21.6	2.0	36.0	11.0	3.8	74.0	2.0	1.6	26.8	32.0	20.0	56.6
16-20	9.4	2.6	78.2	10.6	1.4	26.8	15.2	5.0	91.0	19.2	10.4	26.8
21-25	5.4	0.4	13.4	0.4	3.8	64.0	39.2	32.6	188.0	6.4	7.6	73.2
26-31	4.0	0.3	8.3	4.2	1.0	34.0	15.8	10.8	40.0	1.3	1.5	8.7
Total	45.8	6.9	163.5	44.6	16.8	272.4	84.2	54.4	433.0	75.1	50.9	193.1
June												
1-5	2.4	-	2.8	4.2	0.2	15.4	13.2	7.4	108.6	1.2	0.6	2.2
6-10	1.2	-	1.6	2.2	1.0	15.2	2.2	2.8	54.2	2.2	1.2	8.6
11-15	3.0	1.0	9.8	3.4	0.2	6.4	2.0	0.4	2.0	14.6	23.0	54.4
16-20	5.2	0.6	14.4	0.8	-	2.4	3.2	1.2	64.6	13.6	26.8	96.0
21-25	4.2	0.2	12.6	-	-	1.4	2.0	0.4	24.8	15.2	32.4	38.0
26-30	10.0	2.2	18.0	0.8	0.2	5.4	1.2	0.2	3.8	2.8	7.4	12.4
Total	26.0	4.0	59.2	11.4	1.6	46.2	23.8	12.4	258.0	49.6	91.4	211.6
July												
1-5	0.2	0.4	8.0	7.0	2.6	35.4	9.8	7.0	7.2	5.8	8.0	8.0
6-10	1.8	0.4	2.6	8.0	5.2	55.8	5.2	4.2	10.4	7.8	11.6	13.4
11-15	2.6	2.0	12.6	8.8	9.8	49.6	9.8	2.4	5.2	1.4	1.2	5.2
16-20	8.0	0.2	11.6	1.8	4.0	25.4	11.8	13.0	8.0	1.2	0.8	1.6
21-25	-	0.8	8.6	2.2	3.0	10.4	4.4	3.6	7.2	2.2	1.0	4.0
26-31	1.7	13.3	9.3	-	0.6	5.5	2.8	9.2	8.0	5.2	13.7	17.2
Total	14.3	17.1	52.7	27.8	25.2	182.1	43.8	39.4	46.0	23.6	36.3	49.4
Aug.												
1-5	0.2	-	0.6	0.8	0.2	1.6	1.2	1.2	1.8	0.6	4.2	3.0
6-10	0.4	3.0	1.0	1.2	2.8	0.8	-	0.2	0.8	0.4	1.2	1.4
11-15	-	0.8	3.6	-	0.2	2.4	-	-	0.2	0.4	0.4	0.4
16-20	0.8	0.4	3.2	-	-	-	-	-	0.6	0.2	0.2	-
21-25	-	-	-	-	-	0.4	0.6	0.6	1.0	-	-	-
26-31	-	-	2.0	0.3	-	-	-	-	0.3	-	-	-
Total	1.4	4.2	10.4	2.3	3.2	5.2	1.8	2.0	4.7	1.6	6.0	4.8

TABLE 14

Trap-wise catches of *Holotrichia seticollis* based on 5 day running means for May to October 1964-1966

Dates	1964			1965			1966		
	B	E	K	B	E	K	B	E	K
May									
1-5	-	-	-	-	-	-	-	-	-
6-10	-	0.2	-	-	-	-	0.2	-	0.2
11-15	-	-	-	-	-	-	-	0.2	-
16-20	-	-	-	0.2	-	0.6	-	-	-
21-25	-	-	-	-	-	-	-	0.2	0.6
26-31	-	-	0.3	0.5	0.8	2.8	0.2	-	-
Total	-	0.2	0.3	0.7	0.8	3.4	0.4	0.4	0.8
June									
1-5	-	-	-	1.8	1.0	4.0	-	-	-
6-10	-	-	-	2.6	2.0	10.8	-	-	-
11-15	0.2	0.2	0.2	0.6	0.4	1.4	0.6	-	1.0
16-20	-	-	0.4	0.2	-	1.2	3.2	0.6	7.4
21-25	-	-	0.4	0.2	0.2	2.4	7.6	7.2	20.2
26-30	-	-	-	1.2	0.6	2.2	5.8	5.2	9.6
	0.2	0.2	1.0	6.6	4.2	22.0	17.2	13.0	38.2
July									
1-5	0.8	3.4	2.4	8.4	4.2	23.2	3.6	1.2	2.4
6-10	33.4	7.2	144.0	36.8	21.4	99.6	10.4	6.8	5.8
11-15	56.4	29.8	95.6	11.0	6.6	20.8	0.4	1.0	2.4
16-20	15.8	4.2	21.2	53.0	57.0	61.2	0.2	0.2	0.4
21-25	4.8	3.4	11.2	41.2	42.4	9.4	3.8	2.2	0.8
26-31	1.2	1.7	3.2	9.3	11.8	5.7	5.7	5.3	0.2
Total	112.4	49.1	277.6	159.7	143.4	219.9	24.1	16.7	12.0

(Contd.)

Table 14 (Contd.)

Dates	1964			1965			1966		
	B	E	K	B	E	K	B	E	K
Aug.									
1-5	5.0	1.8	4.2	3.0	4.8	4.6	3.8	9.8	0.8
6-10	4.2	0.8	1.2	0.6	1.6	0.6	2.6	3.2	0.6
11-15	0.4	0.2	0.2	0.6	2.4	0.6	1.4	1.4	0.4
16-20	-	-	0.2	1.4	0.6	1.0	0.4	1.2	0.6
21-25	-	-	0.4	1.4	1.4	2.0	-	-	0.2
26-31	0.3	-	0.5	0.2	0.2	1.2	-	0.2	-
Total	9.9	2.8	8.7	7.2	11.0	10.0	8.2	15.8	2.6
Sep.									
1-5	-	-	-	0.8	0.4	0.6	0.6	-	1.2
6-10	0.2	-	0.4	-	0.2	0.4	1.2	0.6	0.8
11-15	1.0	-	0.2	-	-	0.6	0.8	0.2	0.6
16-20	-	-	0.4	0.8	0.4	1.0	2.0	-	0.2
21-25	0.6	0.4	0.4	1.0	0.2	1.2	1.0	-	-
26-30	0.8	0.6	0.8	0.2	-	-	0.4	-	-
Total	2.6	1.0	2.2	2.8	1.2	3.8	6.0	0.8	2.8
Oct.									
1-5	0.6	0.2	1.8	1.4	0.2	1.4	0.4	-	0.4
6-10	0.4	0.2	0.6	-	0.2	-	0.8	0.2	0.2
11-15	-	-	0.2	0.6	-	0.2	0.6	-	-
16-20	-	-	-	0.4	-	0.4	0.2	-	-
21-25	-	-	-	0.2	-	0.2	-	-	-
26-31	-	-	-	-	0.2	-	-	-	0.2
Total	1.0	0.4	2.6	2.6	0.6	2.2	2.0	0.2	0.8

TABLE 15

Trap-wise catches of Catharsius pithecus based on 5 day running means for May to October 1963-1966.

Dates	1963			1964			1965			1966		
	B	E	K	B	E	K	B	E	K	B	E	K
May												
1-5	-	-	-	-	-	-	-	-	-	-	-	-
6-10	-	-	-	-	-	-	-	-	-	-	-	-
11-15	-	-	-	-	-	-	-	-	-	-	-	-
16-20	-	-	-	-	-	-	-	-	1.2	0.6	1.8	3.2
21-25	-	-	-	-	-	-	0.4	0.2	1.0	-	-	1.0
26-31	-	-	-	-	-	-	3.8	4.0	12.0	-	0.2	-
Total	-	-	-	-	-	-	4.2	4.2	14.2	0.6	2.0	4.2
June												
1-5	-	-	-	-	-	-	0.8	0.6	4.2	-	-	-
6-10	-	-	-	-	-	0.2	0.6	2.0	2.8	-	-	-
11-15	-	-	-	-	-	0.2	-	0.4	-	-	-	1.0
16-20	-	-	-	-	-	-	-	0.2	-	1.2	2.4	4.4
21-25	-	-	-	-	-	-	-	-	0.8	3.4	15.6	80.8
26-30	-	-	-	-	-	-	-	0.4	2.6	2.6	18.8	40.4
July												
1-5	-	0.2	0.2	-	4.4	1.0	0.4	2.0	1.2	3.2	24.4	26.4
6-10	-	0.2	-	5.6	16.2	95.2	0.6	2.8	3.2	13.8	24.0	80.4
11-15	2.4	2.2	0.6	36.4	46.6	666.4	0.6	2.6	1.4	1.0	3.8	24.0
16-20	-	6.0	4.4	7.4	4.0	215.0	15.8	73.0	79.8	2.2	1.6	8.0
21-25	12.8	24.4	8.2	1.8	0.6	21.8	49.6	59.6	199.6	33.2	46.2	88.8
26-31	5.8	11.0	22.2	3.0	2.5	114.0	8.5	39.5	167.2	11.2	41.3	43.3
Total	21.0	44.0	35.6	54.2	74.3	1010.4	75.5	179.5	452.4	64.6	141.3	270.5

(Contd.)

Table 15 (Contd.)

Dates	1963			1964			1965			1966		
	B	E	K	B	E	K	B	E	K	B	E	K
Aug.												
1-5	2.0	1.2	14.6	1.0	13.2	45.6	7.6	18.6	83.6	6.6	23.8	30.0
6-10	6.4	13.8	20.4	1.6	7.4	88.0	0.4	9.4	6.4	27.6	38.8	117.6
11-15	14.2	32.2	62.6	4.4	7.8	40.8	0.2	6.4	3.0	22.6	42.4	137.6
16-20	4.4	31.2	117.8	2.0	2.4	24.8	1.2	14.0	6.6	20.8	46.8	145.6
21-25	5.0	20.4	49.8	1.6	1.4	7.8	5.2	5.8	32.2	5.4	35.8	105.2
26-31	1.0	7.3	31.5	4.0	8.5	39.2	3.5	11.5	34.5	1.2	6.0	6.8
Total	33.0	106.1	296.7	14.6	40.7	246.2	18.1	65.7	166.3	84.2	193.6	442.8
Sep.												
1-5	0.2	0.8	0.8	3.8	15.0	86.0	2.4	6.0	10.0	2.6	15.6	17.4
6-10	2.2	12.4	23.2	3.4	15.2	68.0	0.2	1.6	2.6	7.0	12.4	22.8
11-15	9.2	16.8	33.8	1.0	7.4	27.0	-	0.4	2.0	4.8	7.6	17.6
16-20	0.4	7.4	26.4	0.4	2.0	7.6	-	-	1.4	3.0	4.4	9.0
21-25	1.4	1.8	9.2	0.2	1.0	4.4	0.6	-	1.4	1.8	4.4	5.2
26-30	-	0.2	0.2	0.6	0.6	6.8	-	0.8	1.0	-	0.2	-
Total	13.4	39.4	93.6	9.4	41.2	199.8	3.2	8.8	18.4	19.2	44.6	72.0
Oct.												
1-5	0.2	-	-	1.6	1.6	4.4	-	0.4	0.2	0.4	2.2	0.2
6-10	0.4	0.6	0.8	0.4	0.6	2.8	-	0.2	-	0.2	1.8	0.2
11-15	1.0	1.4	1.6	0.2	1.6	2.0	-	1.6	-	0.4	1.2	-
16-20	0.4	0.4	0.2	-	0.4	0.2	0.4	1.2	-	0.4	0.2	0.2
21-25	-	0.2	0.6	-	0.2	-	0.2	0.4	-	-	-	-
26-31	0.2	-	-	-	-	-	-	0.2	-	-	-	-
Total	2.2	2.6	3.2	2.2	4.4	9.4	0.6	4.0	0.2	1.4	5.4	0.6

TABLE 16

Trap-wise catches of Schizonycha ruficollis based on 5 day running means for May to August 1963-1966

Dates	1963 B	1963 E	1963 K	1964 B	1964 E	1964 K	1965 B	1965 E	1965 K	1966 B	1966 E	1966 K
May												
1-5	-	-	-	-	-	-	-	-	-	-	-	-
6-10	-	-	-	0.4	-	0.6	-	-	0.2	-	-	-
11-15	2.2	0.2	1.4	1.0	0.4	0.8	-	-	-	2.2	-	0.4
16-20	7.4	-	5.2	-	-	0.2	0.4	-	0.4	8.6	-	1.8
21-25	2.0	-	2.2	0.6	-	-	3.6	-	1.0	1.6	0.4	1.2
26-31	0.7	-	2.7	0.8	-	0.2	14.3	1.3	4.0	0.2	-	0.5
Total	12.3	0.2	11.5	2.8	0.4	1.8	18.3	1.3	5.6	12.6	0.4	3.9
June												
1-5	0.6	-	0.4	1.4	-	0.4	10.4	3.8	4.4	-	-	-
6-10	-	-	0.2	0.4	-	0.4	1.8	0.4	1.2	0.2	0.2	-
11-15	2.0	-	0.8	1.2	-	-	2.4	1.0	0.2	0.4	-	0.2
16-20	2.0	-	-	0.4	-	0.8	0.2	-	0.2	5.4	0.8	5.2
21-25	1.4	-	1.0	0.2	-	-	0.4	-	0.4	12.6	4.4	6.8
26-30	3.2	0.4	1.2	0.4	-	-	0.2	-	-	26.2	10.0	15.2
Total	9.2	0.4	3.6	4.0	-	1.6	15.4	5.2	6.4	44.8	15.4	27.4
July												
1-5	7.2	0.4	4.6	0.8	18.6	0.2	1.4	0.4	0.6	16.0	9.0	21.4
6-10	1.8	0.2	1.0	67.2	51.0	88.8	6.2	2.8	2.2	116.8	80.0	63.2
11-15	2.6	1.6	12.0	272.8	154.8	484.0	1.6	0.4	0.4	65.6	47.0	125.6
16-20	31.6	0.2	9.6	156.4	113.6	333.8	168.0	98.4	45.6	14.8	9.8	52.8
21-25	130.0	25.0	69.2	19.6	26.0	29.8	665.0	219.4	210.4	24.8	24.0	42.4
26-31	4.0	2.2	9.3	36.5	45.7	151.0	51.3	145.3	226.7	137.3	62.7	21.3
Total	177.2	29.6	105.7	553.3	409.7	1087.6	893.5	466.7	485.9	375.3	232.5	216.7
Aug.												
1-5	24.2	11.4	4.6	33.4	26.6	156.8	9.4	35.8	67.8	77.2	76.2	19.4
6-10	50.6	24.4	27.8	10.8	10.4	27.6	1.4	1.0	3.2	111.6	100.8	24.0
11-15	50.0	30.2	37.4	2.4	1.6	20.2	0.2	0.4	1.8	43.2	44.0	28.8
16-20	11.0	9.2	27.2	0.6	-	-	0.4	0.6	1.4	9.2	8.4	14.4
21-25	2.0	5.4	20.0	-	-	-	0.8	1.4	1.2	0.6	0.2	0.2
26-31	-	1.3	-	0.3	0.5	0.5	0.8	0.3	1.5	-	-	-
Total	137.8	81.9	117.0	47.5	39.1	205.1	13.0	39.5	76.9	241.8	229.6	86.8

The captures of each species based on 5 day running means, in each month and in each trap has been presented through Tables 10 to 16. This is the data used for analysis.

(B) Analysis

In this section it is proposed to analyse the data with a view to examine the (1) influence of various components of weather on the captures, (2) influence of the location of the trap upon the captures and (3) the period of flight of these insects in the night.

(1) Influence on various components of weather on the captures

The influence of mean daily temperature, mean daily relative humidity, and rainfall on the captures are being analysed. This has been done with the help of the following four methods:

(A) Graphical representation of log. catches against corresponding temperatures and humidities

According to the period of activity these insects can be divided into two groups (Figures 1d to 8d).

Group-I Scarabaeids with long period of activity

1. *Autoserica insanabilis*, and
2. *Apogonia ferruginea*

Group-II Scarabaeids with short period of activity

3. *Adoretus compressus*
4. *Adoretus lasiopygus*

5. Holotrichia seticollis
6. Catharsius pithecus
7. Schizonycha ruficollis, and
8. Anomala ruficapilla

The activities of all the species cease in October and do not begin before March.

Thus it can be seen from figures 1d to 8d that, broadly speaking, one group has a long period of activity (March to October) characterized by more than one peaks whereas the second group has a much shorter period (May/June to September/October) having one or more than one peaks. A. insanabilis and A. ferruginea belong to the first group, whereas the rest fall into the second. Amongst the second group, A. lasiopygus and C. pithecus have one peak period of activity, while the rest have more than one peaks.

Each Scarabaeid shows a characteristic pattern of its activity and the seasons for peaks of activity are specific. The peak of H. seticollis is in late June and July when the temperature and humidity are high (Fig. 3d). But the peak of A. lasiopygus is in September when the humidity is high but temperature is definitely low (Fig. 4d). On the other hand, the peak of A. compressus falls in May when the temperature is still rising but humidity is low (Fig. 5d).

Amongst the two species of Adoretus there is a definite difference in the peaks of their activities. Activity of A. lasiopygus is spread from May to October but of A. compressus from April to August. The peaks are always noticeable even if

Fig. 1D

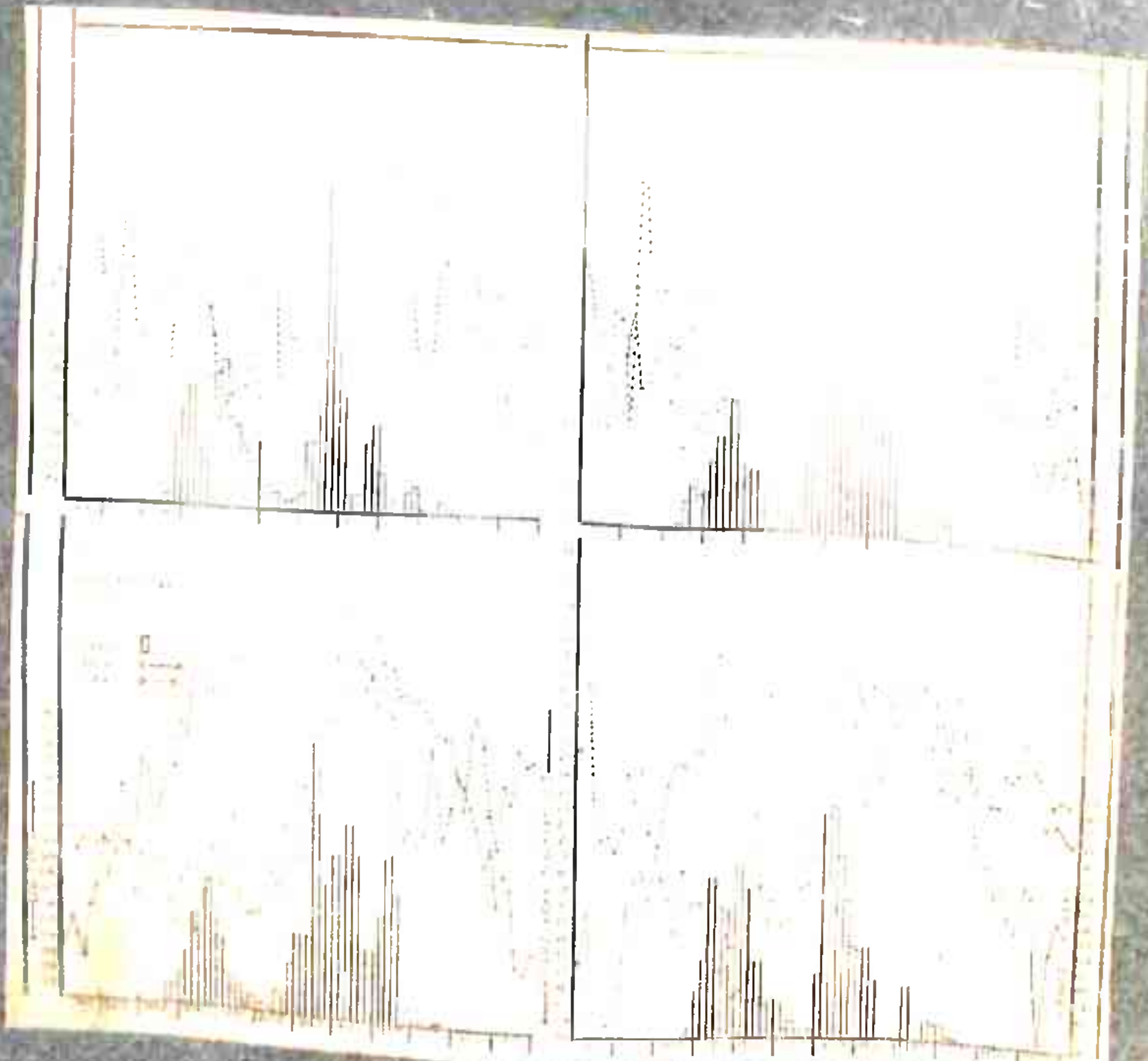


Fig. 20

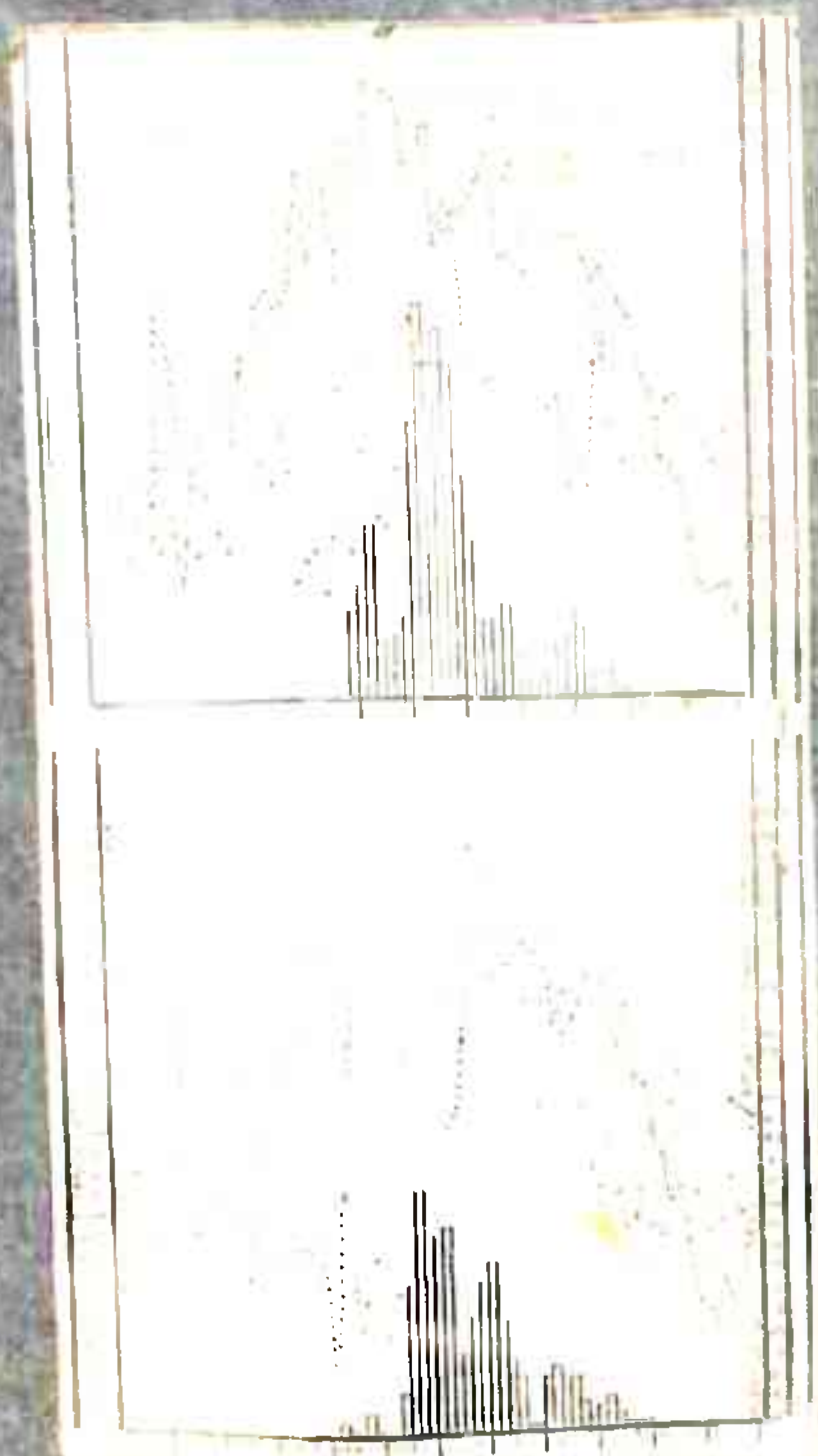
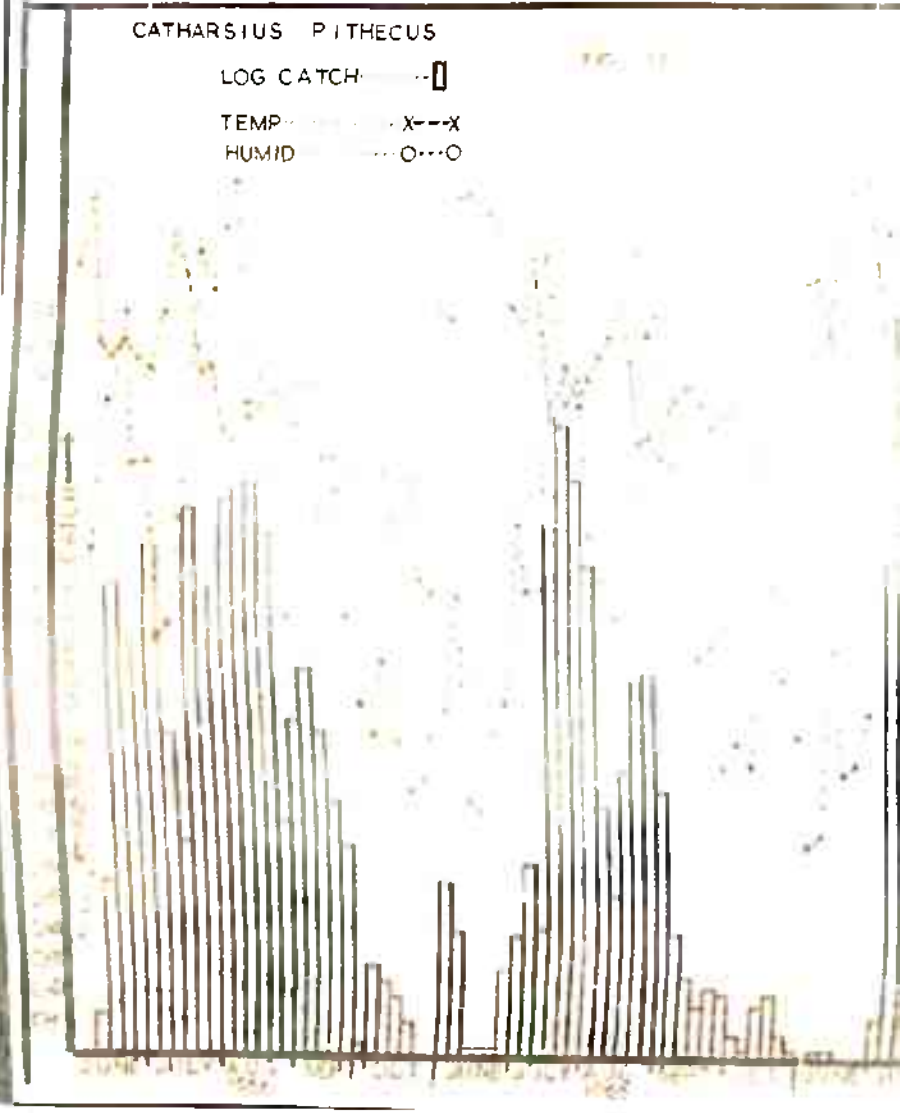
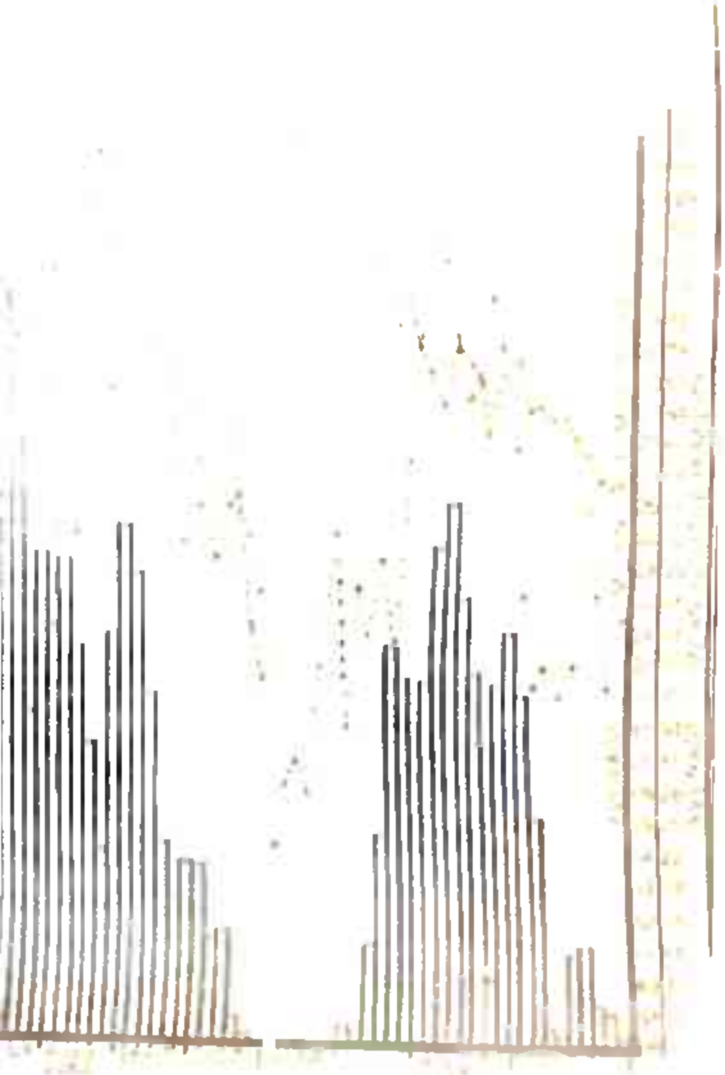


Fig. 30


CATHARSIUS PITHECUS
LOG CATCH
TEMP
HUMID



the frequency of a species is not high. This is particularly true of A. ruficapilla which, although, never very abundant, shows two definite peaks.

(B) Scatter diagrams and regression lines

The effect of temperature and humidity as studied through scatter diagrams and regression lines closely resembles the observations arrived at by the first method. Further, the effect has not only been studied by taking 5-day means but also on the daily catches of some species (all the relevant points of results have been presented through a synoptic Table 17). It can be seen from this table and the figures 1C-B to 7C-B that, except A. compressus, the rest of the species are positively correlated with humidity. The highest value of this, as shown by S. ruficollis, is 0.0523, which means doubling of the catch for a rise of 6% of relative humidity. A. compressus does not show appreciable response to change of humidity. Similarly, the same table and figures 1C-A to 7C-A indicate that four species namely, S. ruficollis, A. lasiopygus, C. pithecus and A. compressus show negative response to temperature. However, the value is not significant at 1% level in the case of the last species. The highest regression value, as shown by S. ruficollis is -.3015, which means the catch is halved by 1°C rise of mean temperature. This is signigicant even at .1% level. Relationships could not be established in the case of H. seticollis and A. ferruginea whereas A. insanabilis shows positive response to temperature. The positive value of regression is .0426 (significant at 5% level only).

TABLE 17

Summary of regression values per unit change of mean temperature and mean relative humidity as worked out from scatter diagrams and regression lines

Species	Regression/°C	Regression/% R.H.
S. ruficollis	-0.3015	+0.0523***
A. lasiopygus	-0.1624	+0.0252
C. pithecus	-0.1550	+0.0224
A. compressus	-0.1000**	±0.0000
H. seticollis	±0.0000	+0.0162**
A. ferruginea	±0.0000	+0.0090*
A. insanabilis	+0.0426*	+0.0135

TABLE 18

Group-data correlations of the log catches of each species on mean temperatures and mean relative humidities

Year	Temp. °C	% R.H.
S. ruficollis		
1963	-0.5460	+0.6433
1964	-0.3448	+0.5723
1965	-0.3604	+0.5612
1966	-0.2082*	+0.6398
A. lasiopygus		
1963	-	-
1964	-0.4022	+0.6165
1965	-0.6145	+0.6708
1966	-0.4681	+0.4326
A. ruficapilla		
1964	-0.4921	+0.5108
1965	-0.3497	+0.4405
1966	-0.0041*	+0.3705
C. pithecus		
1963	-	-
1964	-0.0292*	+0.7032***
1965	-0.1170*	+0.7596***
1966	-0.2121*	+0.8142***
A. insanabilis		
1963	+0.4583	+0.3498
1964	+0.3704	+0.4423
1965	+0.4669	+0.1166*
1966	+0.5144	+0.6368
A. ferruginea		
1963	+0.1957*	+0.5467
1964	+0.2314*	+0.0045*
1965	+0.0390*	+0.3487
1966	+0.3687	+0.5638
H. seticollis		
1964	-	-
1965	+0.1844*	+0.4406
1966	+0.1724*	+0.6841
A. compressus		
1963	+0.2015*	-0.3694**
1964	+0.0334*	-0.1956*
1965	+0.0603*	-0.0890*
1966	+0.2465*	+0.0081*

N.B. * Not significant
** Significant at 5% but not at 1%
*** Significant at 0.1%

which means the catch is doubled by $7^{o}C$ rise of mean temperature.

(C) Group-data-correlations of log. catches on temperatures and humidities

So far none of the workers in this field have used this technique to study the influence of weather factors on the activity of insects. The method of study of the correlation with grouped-data is similar to that of a scatter diagram except that the values of each variate, instead of being plotted exactly, is entered in the appropriate cell. Thus the data are grouped into levels of log. catches against levels of temperatures (Table 19) and levels of humidities (Table 20). In order to illustrate the point, two tables of the most abundant species A. lasiopygus are presented here. The data regarding the other species, are compressed into a synoptic Table 18. The conclusions drawn here are similar to those obtained by the first two methods. Except A. compressus all the species show positive correlations with humidity. The highest response is shown by C. pithecus (correlation value .8142 significant at .1% level). The positive values of correlations are not significant during the years 1964 and 1965 for A. ferruginea and A. insanabilis respectively. The rest of the values for all the species are significant at 1% level of significance. The highest value of negative correlation as shown by A. compressus is -.3694, which is significant at 5% level but not at 1%.

It is clear from the synoptic Table 18 that so far as the effect of temperature is concerned these species fall into two groups. Four species, namely *A. lasiopygus*, *S. ruficollis*, *A. ruficapilla* and *C. pithecus* show negative correlations. However, the values in 1964 to 1966 for *C. pithecus*; and in 1960 for *S. ruficullis* and *A. ruficapilla* are not significant. The rest of the four species show positive correlations, although only one species amongst these (*A. insanabilis*) shows significantly positive values during all the four years.

(D) Simple and partial correlations and regressions of log. catches on temperature and humidity

The simple and partial correlations as well as simple and partial regressions of log. catch on mean temperatures and mean relative humidities for the period 1963 to 1966 have been worked out, based on 5-day running means. Thus each month was divided into six sections. In Tables 21 to 28 the results have been summarized on a monthly basis.

An examination of the Tables 21 to 28 would reveal that although, generally, the results fall in line with those obtained by the preceding three techniques, such as regression lines etc., a closer scrutiny reveals that there are certain differences as well. These differences can be accounted for by the differences in the methods of collating the data. With 5-day running means (as adopted here) the size of the sample becomes considerably smaller than with daily catches and a larger number of observations as adopted in earlier techniques

TABL[E]

The correlation between log. catches of <u>Adoretus</u> <u>lasiopygus</u> with mean Tempe[rature]

Levels of log. catch		Levels of Temperature									
		26.5-27	27-27.5	27.5 28	28-28.5	28.5-29	29-29.5	29.5-30	30-30.5	30.5-31	31-31.[5]
	Mid-value	26.75	27.25	27.75	28.25	28.75	29.25	29.75	30.25	30.75	31.25
.0-.1	.05										0 1 (0)
.1-.2	.15										
.2-.3	.25										0 1 (0)
.3-.4	.35			+56 1 (+56)							
.4-.5	.45										
.5-.6	.55										
.6-.7	.65										
.7-.8	.75					+20 1 (+20)					
.8-.9	.85						+12 1 (+12)				
.9-1.0	.95	+18 1 (+18)							+4 1 (+4)		
1.0-1.1	1.05							+3 1 (+3)		+1 1 (+1)	
1.1-1.2	1.15					0 1 (0)					0 1 (0)
1.2-1.3	1.25										
1.3-1.4	1.35										
1.4-1.5	1.45										
1.5-1.6	1.55				-24 1 (-24)						
1.6-1.7	1.65										

TABL

The correlation between log. catches of Adoretus lasiopygus with mean Relative

Levels of log. catch		Levels of Hu								
		18-22	22-26	26-30	30-34	34-38	38-42	42-46	46-50	50-5
	Mid-value	20	24	28	32	36	40	44	48	52
.0-.1	.05	+77 1 (+77)								
.1-.2	.15		+60 11 (+120)	+50 1 (+50)					0 1 (0)	
.2-.3	.25			+45 11 (+90)		+27 1 (+27)				
.3-.4	.35		+48 1 (+48)			+24 1 (+24)				
.4-.5	.45								0 1 (0)	
.5-.6	.55						+12 1 (+12)		0 1 (0)	
.6-.7	.65									
.7-.8	.75									
.8-.9	.85									
.9-1.0	.95							+2 1 (+2)		
1.0-1.1	1.05									-1 1 (-1)
1.1-1.2	1.15				0 1 (0)				0 1 (0)	
1.2-1.3	1.25									
1.3-1.4	1.35									
1.4-1.5	1.45									
1.5-1.6	1.55							-4 1 (-4)	0 1 (0)	
1.6-1.7	1.65							-7		
1.7-1.8	1.75									

It is clear from the synoptic Table 18 that so far as the effect of temperature is concerned these species fall into two groups. Four species, namely A. lasiopygus, S. ruficollis, A. ruficapilla and C. pithecus show negative correlations. However, the values in 1964 to 1966 for C. pithecus; and in 1966 for S. ruficullis and A. ruficapilla are not significant. The rest of the four species show positive correlations, although only one species amongst these (A. insanabilis) shows significantly positive values during all the four years.

(D) Simple and partial correlations and regressions of log. catches on temperature and humidity

The simple and partial correlations as well as simple and partial regressions of log. catch on mean temperatures and mean relative humidities for the period 1963 to 1966 have been worked out, based on 5-day running means. Thus each month was divided into six sections. In Tables 21 to 28 the results have been summarized on a monthly basis.

An examination of the Tables 21 to 28 would reveal that although, generally, the results fall in line with those obtained by the preceding three techniques, such as regression lines etc., a closer scrutiny reveals that there are certain differences as well. These differences can be accounted for by the differences in the methods of collating the data. With 5-day running means (as adopted here) the size of the sample becomes considerably smaller than with daily catches and a larger number of observations as adopted in earlier techniques

TABLE 21

The correlations and regressions of log. catch of *Adoretus lasiopygus* on mean Temperature and mean Relative Humidity for 1964 to 1966 (on 5 day running means)

Months	Correlation		Regression		Partial Correlation		Partial Regression	
	Temp.	Humidity.	Temp.	Humidity	Temp.	Humidity	Temp.	Humidity
				1964				
May	-.6646	+.6845	-.0365	+.0056	-.3266	+.3861	-.0203	+.0034
June	+.1852	+.6081	+.0082	+.0079	+.2872	+.6345	+.0104	+.0081
July	-.3263	+.3882	-.0772	+.0171	+.0252	+.2240	+.0101	+.0188
Aug.	-.4091	+.5406	-.1152	+.0211	-.1463	+.4090	-.0425	+.0177
Sept.	+.3328	+.5535	+.2781	+.0735	-.1254	+.7028	-.0876	+.0752
				1965				
May	-.8056	+.9832	-.1031	+.0319	-.9741	+.9975	-.0333	+.0262
June	+.1218	+.0953	+.0092	+.0009	+.2603	-.0734	+.0325	+.0074
July	-.7405	+.7015	-.0682	+.0104	-.3482	+.0951	-.0635	+.0014
Aug.	-.6262	+.7865	-.2114	+.0317	+.5385	+.7467	-.2072	+.0713
Sept.	-.0518	+.9323	-.0373	+.0356	+.8731	+.9868	+.1961	+.0401
				1966				
May	-.7716	+.8809	-.0191	+.0063	-.6018	+.8095	-.0113	+.0042
June	-.8628	+.9424	-.0595	+.0062	-.4195	+.8086	-.0161	+.0048
July	-.0183	+.3639	-.0011	+.0024	+.3416	+.4483	+.0323	+.0053
Aug.	+.7854	-.8748	+.1551	-.0451	+.5213	-.7454	+.2287	-.0741
Sept.	+.0832	+.9126	+.0584	+.0746	+.2158	+.9140	+.0645	+.0807

TABLE 22

The correlations and regressions of log. catch of *Catharsius pithecus* on mean Temperature and mean Relative Humidity for 1964 to 1966 (on 5 day running means)

Months	Correlation		Regression		Partial Correlation		Partial Regression	
	Temp.	Humidity	Temp.	Humidity	Temp.	Humidity	Temp.	Humidity
				1964				
June	-.6551	+.2535	-.0045	-.0005	-.6532	+.2601	-.0044	+.0004
July	-.8718	+.6023	-.3448	+.0444	-.8831	-.6454	-.5628	-.0467
Aug.	+.6215	-.5316	+.0929	-.0106	+.4563	-.2705	+.0741	-.0056
Sept.	+.3663	+.8427	+.1760	+.0481	-.2253	+.8235	-.0767	+.0532
Oct.	+.1908	+.4217	+.0112	+.0275	+.0462	+.3852	+.0033	+.0261
				1965				
June	-.9073	+.6828	-.1216	+.0235	-.8028	-.1165	-.1441	-.0074
July	-.8638	+.8429	-.3345	+.0516	-.4251	+.2723	-.2473	+.0145
Aug.	-.5533	+.5154	-.1134	+.0125	-.2461	-.0245	-.1323	-.0024
Sep.	-.6560	+.9021	-.2090	+.0157	-.8216	+.9452	-.1226	+.0130
Oct.	-.5534	+.9463	-.0229	+.0061	-.9983	+.9982	-.1156	+.0152
				1966				
June	-.4038	+.7908	-.1271	+.0216	+.3539	+.7907	+.1525	+.0243
July	-.6243	+.4256	-.1333	+.0107	-.5817	-.0872	-.1563	-.0027
Aug.	+.0319	+.5028	+.0165	+.0146	+.5838	+.7187	+.3805	+.0308
Sep.	+.0172	+.9331	+.0055	+.0344	+.0712	+.9308	+.0085	+.0349
Oct.	+.5601	+.5563	+.0382	+.0153	+.5048	+.4908	+.0327	+.0121

TABLE 23

The correlations and regressions of log. catch of Schizonycha ruficollis on mean Temperature and mean Relative Humidity for 1963 to 1966 (on 5 day running means)

Months	Correlation		Regression		Partial Correlation		Partial Regression	
	Temp.	Humidity	Temp.	Humidity	Temp.	Humidity	Temp.	Humidity
				1963				
May	-.1817	-.1615	-.0233	-.0062	-.3608	-.3521	-.0585	-.0167
June	-.9405	+.7643	-.0991	+.0088	-.9252	-.6694	-.1494	-.0061
July	-.7643	-.1965	-.2123	-.0115	-.9636	-.9136	-.3038	-.0452
Aug.	-.0928	+.7534	-.0615	+.0633	+.3424	+.7462	+.1742	+.0734
				1964				
May	-.6721	+.5719	-.0212	+.0088	-.4523	+.1215	+.0444	+.0141
June	-.5034	-.4525	-.0141	-.0036	-.6091	-.5672	-.0153	-.0048
July	-.8256	+.5436	-.2442	+.0318	-.8442	-.6145	-.4254	-.0393
Aug.	+.7618	-.8172	+.2508	-.0381	+.6037	-.7067	+.1428	-.0274
				1965				
May	+.2419	+.3428	+.0351	-.0125	+.6709	+.7026	+.0033	-.0121
June	-.7846	+.3329	-.1347	+.0138	-.8904	-.7508	-.2352	-.0308
July	-.8653	+.8637	-.4352	+.0683	-.4253	+.2715	-.3273	+.0192
Aug.	-.0352	-.1396	-.0086	-.0048	-.4917	-.4908	-.4256	-.0524
				1966				
May	+.0154	-.1114	+.0005	-.0018	-.0573	-.1234	-.0038	+.0020
June	-.3709	+.7915	-.0841	+.0176	+.3931	+.7785	+.0928	+.0228
July	+.3902	-.3111	+.0644	-.0065	+.2672	-.0165	+.0616	-.0006
Aug.	-.6783	+.8929	-.7034	+.0474	-.1943	+.8047	-.1424	+.0425

TABLE 24

The correlations and regressions of log. catch of Anomala ruficapilla on mean Temperature and mean Relative Humidity for 1964 to 1966 (on 5 day running means)

				1964				
June	-.6524	-.3834	-.0076	-.0012	-.7408	-.5719	-.0074	-.0014
July	-.7115	+.7218	-.1762	+.0334	-.2443	+.3083	-.0835	+.0263
Aug.	+.4062	-.3653	+.0144	-.0018	+.2546	+.1752	+.0104	-.0009
				1965				
May	-.0519	+.6118	-.0051	+.0154	+.6109	+.7816	+.0635	+.0260
June	-.5031	+.0356	-.0224	+.0033	-.7842	-.7082	-.0363	-.0025
July	-.3625	+.4323	-.0316	+.0062	+.0843	+.2645	+.0251	+.0087
				1966				
May	-.0528	+.0834	-.0003	+.0001	-.0090	+.0632	+.0000	+.0001
June	-.5056	+.8827	-.0261	+.0042	+.3421	+.8553	+.0121	+.0053
July	+.8406	-.6609	+.0143	-.0013	+.7085	-.0837	+.0131	-.0001

TABLE 25

The correlations and regressions of log. catch of Holotrichia seticollis on mean Temperature and mean Relative Humidity for 1965 and 1966 (on 5 day running means)

Months	Correlation		Regression		Partial Correlation		Partial Regression	
	Temp.	Humi-dity	Temp.	Humi-dity	Temp.	Humi-dity	Temp.	Humi-dity
				1 9 6 5				
May	+.5918	-.1562	+.0434	-.0026	+.6752	+.4095	+.0609	+.0081
June	-.9263	+.9171	-.1192	+.0298	-.8089	+.7663	-.0645	+.0171
July	-.2084	+.1077	-.0355	+.0024	-.2664	-.2052	-.1133	-.0145
Aug.	+.0046	-.0918	+.0004	-.0012	-.2493	-.2575	-.0682	-.0087
Sep.	-.5036	-.5954	-.0824	-.0053	-.9342	-.9536	-.0970	-.0073
Oct.	+.4715	-.0128	+.0244	-.0000	+.7701	+.6902	+.0633	+.0087
				1 9 6 6				
May	+.4081	+.1365	+.0352	+.0003	+.5580	+.4407	+.0563	+.0082
June	-.5118	+.8915	-.1062	+.0173	+.3476	+.8680	+.0481	+.0206
July	-.4572	-.0093	-.0670	-.0001	-.6901	-.5911	-.1627	-.0145
Aug.	-.7035	+.8828	-.2461	+.0169	-.3023	+.7701	-.0627	+.0182
Sep.	-.0615	+.9026	-.0037	+.0062	-.1173	+.9011	-.0031	+.0062
Oct.	+.7026	+.8515	+.0173	+.0112	+.9080	+.9512	+.0117	+.0092

TABLE 26

The correlations and regressions of log. catch of Adoretus compressus on mean Temperature and mean Relative Humidity for 1963 to 1966 (on 5 day running means)

Months	Correlation Temp.	Correlation Humi-dity	Regression Temp.	Regression Humi-dity	Partial Correlation Temp.	Partial Correlation Humi-dity	Partial Regression Temp.	Partial Regression Humi-dity
				1 9 6 3				
April	+.7018	+.0256	+.1694	+.0017	+.7427	-.3483	+.1974	-.0321
May	-.8451	+.5406	-.1555	+.0300	-.7650	+.0450	-.2015	+.0025
June	-.8628	+.7259	-.2071	+.0192	-.6529	-.1075	-.2752	-.0083
July	-.5443	-.3226	-.0618	-.0085	-.8193	-.7508	-.0973	-.0206
Aug.	-.2671	+.7309	-.0573	+.0216	+.0871	+.7134	+.0147	+.0226
				1 9 6 4				
April	+.8034	-.6208	+.1108	-.0392	+.7843	-.6156	+.1098	-.0185
May	-.7018	+.3461	-.0473	+.0035	-.7033	-.3528	-.0656	-.0041
June	-.6431	-.3635	-.0892	-.0145	-.7194	-.5373	-.0936	-.0176
July	-.2325	+.3129	-.0426	+.0109	+.0847	+.2294	+.0188	-.0133
Aug.	+.7449	-.7018	+.0615	-.0082	+.5809	-.5035	+.0422	-.0046
				1 9 6 5				
April	+.5315	-.7028	+.1293	-.0493	-.1507	-.5543	-.0542	-.0511
May	-.3816	+.9023	-.0563	+.0344	+.6908	+.9430	+.0625	+.0450
June	-.8721	+.5133	-.1631	+.0236	-.9018	-.5862	-.2353	-.0234
July	-.5018	+.5234	-.0515	+.0086	-.0765	+.1817	-.0170	+.0062
Aug.	-.2708	+.2093	-.0226	+.0018	-.2465	-.1643	-.0525	-.0041
				1 9 6 6				
April	+.7231	-.2024	+.1345	-.0285	+.7281	+.2528	+.1535	+.0296
May	-.3082	+.5636	-.0249	+.0135	-.0188	+.4960	-.0005	+.0134
June	-.7025	+.8416	-.1573	+.0177	-.2932	+.7080	-.0421	+.0155
July	-.5613	+.1428	-.1023	+.0034	-.7058	-.5092	-.1917	-.0143
Aug.	-.7072	+.8065	-.2026	+.0114	-.3553	+.6205	-.0943	+.0082

TABLE 27

The correlations and regressions of log. catch of *Apogonia ferruginea* on mean Temperature and mean Relative Humidity for 1963 to 1966 (on 5 day running means)

Months	Correlation		Regression		Partial Correlation		Partial Regression	
	Temp. °C	Humidity	Temp. °C	Humidity	Temp. °C	Humidity	Temp. °C	Humidity
				1 9 6 3				
March	+.1415	-.2424	+.0213	-.0113	+.0525	-.2023	+.0081	+.0091
April	+.6314	-.0851	+.0683	-.0032	+.6418	+.2087	+.0765	+.0082
May	-.2625	+.0637	-.0187	+.0015	-.2723	+.1223	-.0226	-.0048
June	+.7838	+.8028	-.0745	+.0081	-.1337	+.4045	-.0229	+.0062
July	-.4918	+.3639	-.1385	+.0224	-.3945	+.1844	-.1166	+.0104
Aug.	-.0727	+.7645	-.0354	+.0454	+.5064	+.8063	+.1354	+.0530
Sep.	+.7843	+.2815	+.4263	+.0071	+.7827	+.0252	+.4181	+.0006
Oct.	+.3321	+.3328	+.0053	+.0007	+.7427	+.7518	+.0158	+.0026
				1 9 6 4				
March	+.6075	-.1563	+.0072	-.0007	+.6071	+.1423	+.0081	+.0005
April	+.8826	-.3915	+.1282	-.0164	+.7208	+.3127	+.1171	+.0123
May	+.7835	-.7928	+.1582	-.0241	+.4815	-.5223	+.0934	-.0141
June	-.4618	-.2734	-.0186	-.0026	-.6062	-.3843	-.0218	-.0031
July	-.7413	+.5302	-.1608	+.0226	-.6515	-.3132	-.2345	-.0161
Aug.	+.6924	-.7183	+.0837	-.0237	+.5034	-.5348	+.0023	-.0228
Sep.	-.3456	-.0529	-.0423	-.0007	-.3746	+.1744	-.0564	+.0029
Oct.	+.4818	+.3817	+.0052	+.0044	+.3952	+.2486	+.0046	+.0027
				1 9 6 5				
March	+.6047	+.7519	+.0656	+.0123	+.8053	+.8716	+.0586	+.0111
April	+.1828	-.4828	+.0144	-.0089	-.5402	-.6128	-.0632	-.0216
May	+.2935	-.5273	+.0255	-.0115	-.0913	-.4634	-.0092	-.0131
June	-.5663	+.5456	-.0094	+.0021	-.2717	+.0172	-.0067	+.0008
July	-.7871	+.8547	-.3081	+.0526	-.0325	+.5408	-.0254	+.0482
Aug.	-.6528	+.5538	-.0957	+.0127	-.4515	-.1961	-.1543	-.0074
Sep.	-.0965	+.2629	-.0105	+.0016	+.0011	+.2459	+.0003	+.0016
Oct.	-.5946	+.7554	-.0092	+.0021	+.0253	+.5743	+.0003	+.0021
				1 9 6 6				
March	+.5862	-.0819	+.0238	-.0019	+.6291	+.3082	+.0308	+.0045
April	+.5734	+.0425	+.0454	+.0024	+.6774	+.4461	+.0612	+.0254
May	+.5518	-.6937	+.0191	-.0045	+.3035	+.5627	+.063	-.0015
June	-.5329	+.9071	-.0961	+.0153	+.3128	+.8745	+.0375	+.0174
July	-.6437	+.3062	-.1206	+.0078	-.6637	-.3544	-.1736	-.0084
Aug.	-.7351	+.9652	-.4372	+.0319	-.3760	+.9255	-.0721	+.0275
Sep.	-.0514	-.1464	-.0038	-.0012	-.0521	-.1432	-.0038	-.0011
Oct.	+.0527	-.0739	+.0007	-.0005	+.0733	-.0896	+.0016	-.0006

TABLE 28

The correlations and regressions of log. catch of *Autoserica insanabilis* on mean Temperature and mean Relative Humidity for 1963 to 1966 (on 5 day running means)

Months	Correlation		Regression		Partial Correlation		Partial Regression	
	Temp.	Humidity	Temp.	Humidity	Temp.	Humidity	Temp.	Humidity
1963								
Mar.	+.2734	-.7026	+.0174	-.0143	-.0154	-.6734	-.0006	-.0142
Apr.	+.9758	-.2013	+.0883	-.0064	+.9852	+.6658	+.0964	+.0084
May	-.2872	+.0113	-.0175	+.0002	-.3573	-.2173	-.0273	-.0048
June	-.5347	+.4033	-.0692	+.0056	-.4964	-.2344	-.0285	-.0072
July	+.0129	+.4151	+.0015	+.0132	+.2426	+.4645	+.0358	+.0165
Aug.	+.7362	+.1502	+.1538	+.0034	+.9121	+.7963	+.1967	+.0148
Sep.	+.6943	-.1983	+.1756	-.0025	+.8238	-.6324	+.3616	+.0058
Oct.	+.5356	-.0605	+.0554	-.0008	+.6545	+.4415	+.0908	+.0074
1964								
Mar.	+.5515	-.1054	+.0384	-.0031	+.5438	-.1712	+.0338	+.0629
Apr.	+.2110	-.3102	+.0257	-.0115	-.2346	-.3345	-.0651	-.0288
May	+.5080	-.7111	+.0466	-.0106	-.0381	-.5836	-.0035	-.0104
June	+.4103	+.3389	+.0183	+.0043	+.4660	+.4170	+.0193	+.0047
July	-.8168	+.5987	-.0858	+.0112	-.7393	-.3646	-.1175	-.0084
Aug.	+.7317	-.5271	+.0843	-.0084	+.6145	-.2033	+.0702	-.0024
Sep.	+.0781	+.7405	+.0212	+.0233	-.5862	+.8445	-.1262	+.0315
Oct.	+.7769	+.4679	+.0283	+.0145	+.7371	+.3642	+.0186	+.0076
1965								
Mar.	+.6557	+.7088	+.0682	+.0108	+.6452	+.8531	+.0563	+.0171
Apr.	+.4252	-.5435	+.0322	-.0093	-.0734	-.3854	-.0016	-.0093
May	-.1624	+.3328	-.0164	+.0086	+.0881	+.3042	+.0095	+.0096
June	+.7430	-.4292	+.1653	-.0237	+.7332	+.4059	+.2381	+.0223
July	-.5024	+.7881	-.0781	+.0171	+.8018	+.9438	+.1825	+.0456
Aug.	+.0002	-.1954	+.0000	-.0008	-.5324	-.5671	-.0579	-.0071
Sep.	-.1563	-.7468	-.0343	-.0085	-.6536	-.8529	-.0957	-.0098
Oct.	+.7281	-.2342	+.0562	-.0033	+.8832	+.7748	+.1093	+.0128
1966								
Mar.	+.8067	-.2251	+.0460	-.0043	+.8218	+.3641	+.0556	-.0051
Apr.	+.3129	+.5443	+.0270	+.0356	+.7832	+.8355	+.0657	+.0635
May	-.3741	+.6192	-.0090	+.0048	-.0709	+.5254	-.0024	+.0036
June	-.6152	+.9238	-.0800	-.0647	+.4328	+.8729	+.0107	+.0115
July	+.0838	-.3342	+.0090	-.0047	-.2752	-.4183	-.0478	-.0092
Aug.	+.0349	+.4756	+.0060	+.0052	+.5418	+.6751	+.1351	+.0097
Sep.	-.0056	+.8471	-.0009	+.0171	+.0063	+.8443	+.0006	+.0178
Oct.	+.9272	+.5828	+.0250	+.0086	+.9545	+.8352	+.0223	+.0046

(regression lines and group-data correlations). As a result of this, correlation values as high as .8 appear to be significant. On the contrary, if the number of observations in a sample are more (as in the case of group data correlations) correlation values as small as .3 are statistically significant. Thus, it would not be wrong to assume that many of the correlation values which are slightly less than .8 are also significant although the small size of the samples have tended to mask it. In other words, the months for which correlation values are less than .8, but approximate to this show significant correlations (if instead of 5-day running means, daily catches would have been used for analysis). Therefore, although many of the correlation values given in the Tables 21 to 28 are apparently not significant but really it is not so.

Four species namely, A. lasiopygus, C. pithecus, S. ruficollis and A. ruficapilla show positive correlations and regressions with humidity and negative with temperature (Tables 21 to 24). The negative values for humidity and positive ones for temperature of these species are not significant except for August 1966 (in the case of A. lasiopygus) and August 1964 (rest three species). The meteorological data reveals that the August of 1964 is significantly different from other years. During the last 15 days of this month the mean temperature is more than 1°C less than for the other three years. The highest value of positive correlation is .9832 shown by A. lasiopygus in the month of May, 1965. The corresponding regression value is .0319 (highly significant even at .1% level of significance) which means doubling of catch by an increase of 9.7% mean relative humidity. The highest negative correlation with temperature -.9405 is shown by S. ruficollis in the month of June, 1963. The corresponding regression value is -.0991, which means the catch is halved by an increase of 3°C in mean temperature, whereas the value of partial regression shows the halving of catch by a rise of 2°C in mean temperature.

The two species, namely A. insanabilis and A. ferruginea are seen to be equally influenced by both temperature and humidity (as has been observed in earlier techniques, Synoptic Table 18) and the correlation values indicate that these species have no preference for either high temperature or high humidity. In March and April these are positively correlated with temperature and negatively with humidity i.e. when the temperature is comparatively low. But in summer months, May and June, usually the reverse is the case. Again towards the end of activity in September and October positive relationship with temperature is observed (Tables 27 and 28).

The remaining two species prefer humidity at high temperatures only, and many insignificant values of correlations and regressions with temperature and humidity are obtained (Tables 25 and 26). This fact can also be noticed from figures 3D and 5D.

(E) The effect of rainfall

Rainfall has two direct consequences: (1) it lowers the temperature, and (2) it increases the humidity.

Both these effects influence the semi-arid climate of Pilani profoundly. It has already been mentioned in the preceding paragraphs that, although, the species under present investigation are active during the summer months, yet except A. insanabilis, none shows positive correlation with temperature. Further, except A. compressus, all show positive correlations with humidity. Hence, it is expected that rainfall should affect the captures of these species in light traps. This becomes apparent when the annual rainfalls are compared with annual captures (cf. Tables 3 and 8). The year 1964 has the highest rainfall (520 mm) which is almost one-third of the total rainfall of 4 years, also shows 45.5% catch of the total catches of 4 years. Similarly, the next higher year both in amount of rainfall (382.6 mm) and catch (20.9%) is 1963. The other two years have almost equal amount of rainfall and catch.

Secondly, four species namely, A. ruficapilla, A. lasiopygus, S. ruficollis and C. pithecus which show highly significant correlations with humidity (at .1% level) also show the highest captures during 1964. The respective percentages of their captures in 1964 are, 61%, 50%, 35% and 35%.

The comparable data of rainfalls and captures show that the rains have positive effect on captures. No statistical analysis has been done to study this effect and the conclusions have been drawn after comparing the nights without rainfall with those with rainfall. The following table will illustrate the point.

TABLE 29

Dates	Day Rain (mm)	Night Rain (mm)	Catch		
			Previous night	Night in question	Following night
4-5/7/64	26.3	-	1	92	4
10-11/7/64	113.8	-	296	400	1244
24-25/7/64	-	61.0	69	30	37

The yearly change in the amount of rainfall and log. catch is, an increase of 5 mm in rainfall has increased the log. catch by .067. However, the highest captures are obtained in nights followed by heavy showers a day earlier. Light rains upto 5 mm during night have not affected the captures especially in the case of S. ruficollis and A. ruficapilla.

(2) Influence of the location of the trap upon the captures

When the catches of one trap are carefully compared with that of another trap, certain salient differences are noticed (Tables 10 to 16). Trap 'K' always has higher catches than the other two traps. This difference, after working out the analysis of variance (Tables 30 and 31), is found to be due to the differences in flora surrounding the traps and is not at random. The flora around each trap are listed separately (Table 34). Secondly, the differences in the captures of the traps are species specific and do not hold good for all species for any particular trap.

From the Tables 10 to 16 it is obvious that, except S. ruficollis and A. ruficapilla which are most abundant in

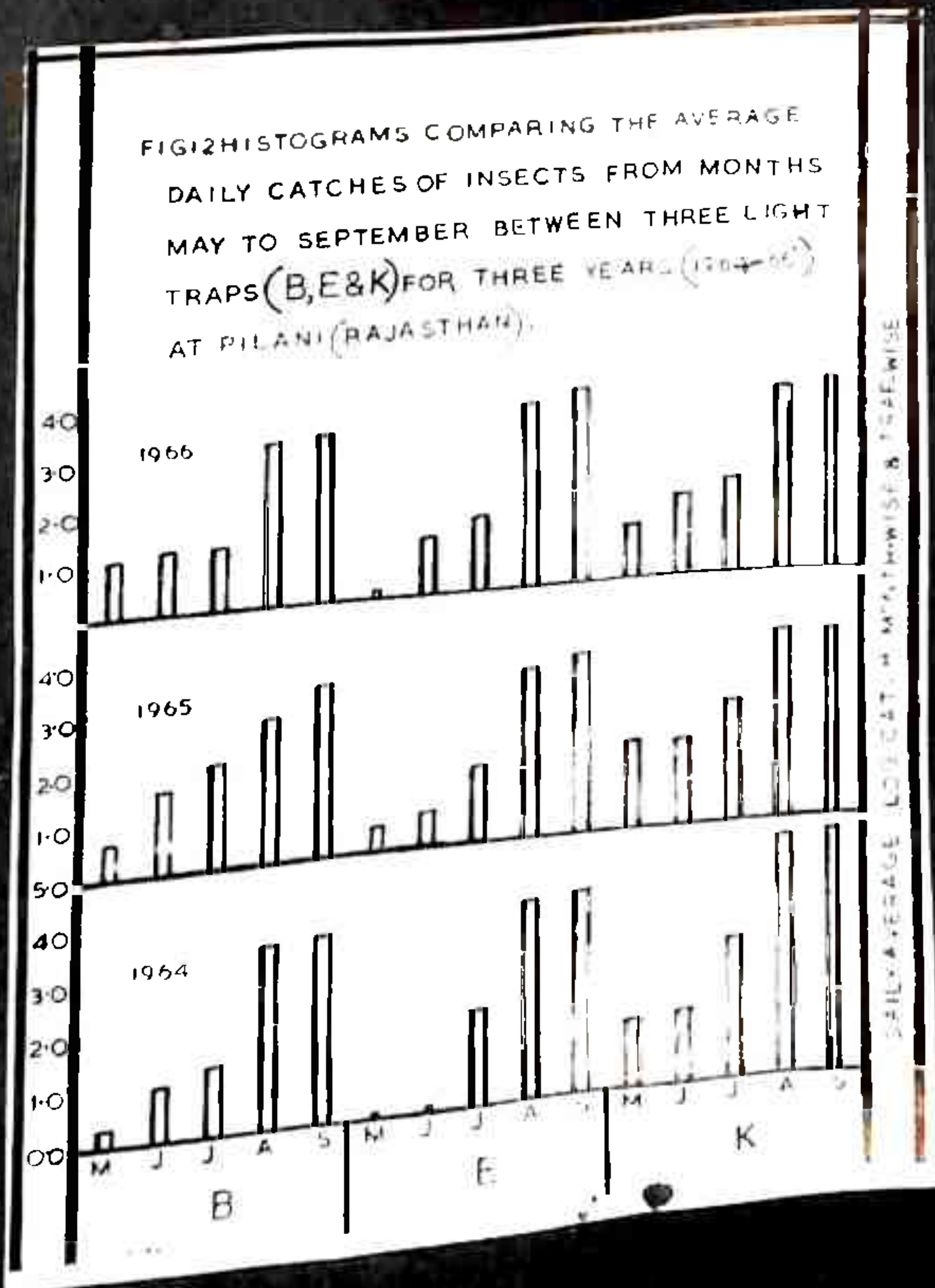


FIG.12 HISTOGRAMS COMPARING THE AVERAGE DAILY CATCHES OF INSECTS FROM MONTHS MAY TO SEPTEMBER BETWEEN THREE LIGHT TRAPS (B,E&K) FOR THREE YEARS AT PILANI (RAJASTHAN).
1966
1965
1964
4·0
3·0
2·0
1·0
5·0
0·0
M
J
J
A
S
B
E
K

Fig. 12

TABLE 30

Analysis of variance between the catches of three traps of *Adoretus lasiopygus* for August and September 1964-1966 (on 5 day totals)

Days	1964			1965			1966		
	B	E	K	B	E	K	B	E	K
Aug.									
1-5	40	183	854	25	35	78	3	2	5
6-10	21	57	327	26	23	92	11	54	36
11-15	229	229	1088	20	48	100	97	357	506
16-20	332	512	2136	57	190	432	185	664	854
21-25	384	528	3308	73	271	1416	542	1542	2124
26-31	1872	3920	32580	419	1648	3506	755	1820	1424
Sep.									
1-5	1920	4402	39034	1079	1023	2042	761	1740	2260
6-10	742	1282	6504	576	1262	1192	959	2513	2494
11-15	405	627	1240	260	560	760	143	1900	1704
16-20	64	285	572	109	317	529	43	201	189
21-25	33	50	250	41	95	42	6	43	38
26-30	7	87	656	15	48	135	4	17	12
Total	6049	12234	88549	2700	5520	10705	3509	10853	11646

$N = 108$

$\Sigma X = 151765$

$(\Sigma X)^2 = 23032615225$

$\Sigma X^2 = 2775306981$

$$\text{Variation between column means} = \frac{\sum_{1}^{K_c}\left(\sum_{1}^{N_c} X\right)^2}{N_c} - \frac{(\Sigma X)^2}{N}$$

$$= \frac{(6049)^2 + (12234)^2 + (88549)^2 + (2700)^2 + (5520)^2 + (10705)^2 + (3509)^2 + (10853)^2 + (11646)^2}{12} - \frac{23032615225}{108}$$

$= 490507876.6$

$$\text{Variation within columns} = \sum X^2 - \frac{\sum_{1}^{K_c} \left(\sum_{1}^{N_c} X \right)^2}{N_c}$$

$$= 2775306981 - 703772832.4 = 2071534148.6$$

Summary of computations for analysis of variance

Source of variation	Amount of variation	Degree of freedom	Estimated variance
Between column means	490507876.6	8	61313484.5
Within columns	2071534148.6	99	20924587.4

$$F = \frac{61313484.5}{20924587.4} = 2.93$$

With $n_1 = 8$ and $n_2 = 99$. The F table of Appendix M does not contain a row for $n_2 = 99$, but it is, nevertheless, clear that the probability of getting $F > 2.93$ is much less than .01 or 1%. Hence there is a real difference between the catches of three traps.

TABLE 31

Analysis of variance between the catches of three traps of *Catharsius pithecus* for 16th June to 25th September 1966 (on 5 day totals)

Dates	B	B^2	E	E^2	K	K^2
June						
16-20	6	36	12	144	22	484
21-25	17	289	78	6084	404	163216
26-30	13	169	94	8836	202	40804
July						
1-5	16	256	122	14884	132	17424
6-10	69	4761	120	14400	400	160000
11-15	5	25	19	361	120	14400
16-20	11	121	8	64	40	1600
21-25	166	27556	231	53361	444	197136
26-31	67	4489	248	61504	260	67600
Aug.						
1-5	33	1089	119	14161	150	22500
6-10	138	19044	194	37636	588	345744
11-15	113	12769	212	44944	688	473344
16-20	104	10816	234	54756	728	529984
21-25	27	729	179	32041	526	276676
26-31	7	49	36	1296	41	1681
Sep.						
1-5	13	169	78	6084	77	5929
6-10	35	1225	62	3844	114	12996
11-15	24	576	38	1444	88	7744
16-20	15	225	22	484	45	2025
21-25	9	81	22	484	26	676
Total	888	84474	2128	356812	5075	2321963

$$N = 60$$

$$\sum X = 8091$$

$$(\sum X)^2 = 65464281$$

$$\sum X^2 = 2763249$$

$$\text{Variation between column means} = \frac{\sum_{1}^{K_c}\left(\sum_{1}^{N_c} X\right)^2}{N_c} - \frac{(\sum X)^2}{N}$$

$$= \frac{(888)^2 + (2128)^2 + (5075)^2}{20} - \frac{65464281}{60}$$

$$= 462556.3$$

$$\text{Variation within column} = \sum X^2 - \frac{\sum_{1}^{K_c}\left(\sum_{1}^{N_c} X\right)^2}{N_c}$$

$$= 2763249 - 1553627.6 = 1209621.4$$

Summary of computations for analysis of variance

Source of variation	Amount of variation	Degree of freedom	Estimted variance
Between column means	462556.3	2	231278.1
Within columns	1209621.4	57	21221.8

$$F = \frac{231278.1}{21221.8} = 10.9$$

With $n_1 = 2$ and $n_2 = 57$. The F table of Appendix M does not contain a row for $n_2 = 57$, but it is, nevertheless, clear that the probability of getting $F > 10.9$ is much less than .001 or .1%. Hence there is a real difference between the catches of three traps.

TABLE 34

The plants around each trap listed trap-wise

Species	Family	B	E	K
Acrachne racemosa	(Graminae)	-	-	+
Aristida mutabilis	"	+	-	-
Arundo donax	"	+	-	-
Brachiaris ramosa	"	+	+	+
Cenchrus biflorus	"	+	+	+
C. ciliaris	"	-	-	+
Cynodon dactylon	"	+	-	+
Cyperus rotundus	"	-	+	-
C. arinarius	"	-	+	-
Dactyloctenium aegyptium	"	+	+	+
Desmostachya bipinnata	"	-	-	+
Digitaria adscendens	"	-	+	+
Eragrostis ciliaris	"	-	-	+
E. poaeoides	"	-	-	+
E. plumosa	"	-	-	+
E. tremula	"	-	-	+
Pennisetum typhoideum	"	-	+	+
Perotis hordeiformis	"	+	-	+
Saccharum munja	"	-	-	+
Setaria glauca	"	-	-	+
Sorghum vulgare	"	-	-	+
Tragus biflorus	"	-	-	+
Triticum vulgare	"	-	-	+
Zea mays	"	-	-	+
Albizzia lebbeck	(Leguminocae)	-	+	-
Acacia arabica	"	+	+	+
Bauhina veriegata	"	+	-	-
Butea frondosa	"	+	-	-
Cassia saimea	"	+	+	-
Caesalpinia pulcherima	"	-	-	+
Cicer artietinum	"	-	-	+
Dalbergia sissoo	"	-	-	+
Delonix regia	"	-	-	+
Parkinsonia aculeata	"	+	+	+
Phaseolus mungo	"	-	-	+
P. radiatus	"	-	-	+
Prosopis juliflora	"	+	+	+
P. spicigera	"	+	+	+
Tamarindus indica	"	+	-	+
Tephrosia purpurea	"	-	+	-
Datura alba	(Solanaceae)	+	-	+
Lycopersicum esculentum	"	-	-	+
Solanum nigrum	"	+	-	+
S. melongena	"	-	-	+
S. lycopersicum	"	-	-	+

Table 34 (Contd.)

Species	Family	Localities H	E	K
Withania somnifera	(Solanaceae)	+	-	-
Jacavanda mimisaefolia	(Bignoniceae)	-	+	-
Kigelia pinnata	"	-	-	+
Millingtonia hortensis	"	-	-	+
Tecoma stans	"	+	-	+
Tecomella undulata	"	+	-	+
Carissa carandas	(Apocynaceae)	-	-	+
Ervatamia coronaria	"	-	-	+
Nerium odonum	"	+	+	+
Vinca rosa	"	+	-	-
Calligonum polygonoides	(Polygonaceae)	+	-	+
Polygonum glabnum	"	+	-	-
Rumex vesicarius	"	+	-	+
Calotropis procera	(Asclepiadaceae)	+	+	+
Cryptostegia grandiflora	"	+	-	-
Leptademia pyrotechnica	"	-	+	-
Ficus benghalensis	(Moraceae)	-	-	+
F. religiosa	"	-	-	+
Morus alba	"	+	-	+
Aerva tomentosa	(Amaranthaceae)	+	-	-
Amaranthus sp.	"	+	-	+
Pupalia lappacea	"	-	+	+
Euphorbia tirucalli	(Euphorbiaceae)	+	-	-
Ricinus communis	"	+	-	+
Citrullus sp.	(Cucurbitaceae)	+	-	+
Momordica charantia	"	-	-	+
Azadirachta indica	(Meliaceae)	-	+	+
Melia azadirachta	"	+	-	+
Althaea rosea	(Malvaceae)	-	-	+
Sida cordifolia	"	+	-	-
Vernonia cinerea	(Compositae)	+	-	+
Artimissia sp.	"	-	-	+
Asparagus sp.	(Liliaceae)	+	-	+
Aloe vera	"	-	-	+
Argemone mexicana	(Papaveraceae)	+	-	+
Chenopodium album	(Chenopodiaceae)	+	-	+
Opuntia sp.	(Opuntiaceae)	+	+	-
Punica grantum	(Punicaceae)	+	-	+
Moringa pterygosperma	(Moringaceae)	+	-	+
Psidium guyava	(Myrtaceae)	+	-	+
Salvadora oleoides	(Salvadoraceae)	+	+	-
Tamarix dioica	(Tamaricaceae)	+	-	+
Heliotropium indicum	(Boraginaceae)	+	-	-
Linaria sp.	(Scrophulariaceae)	+	-	-

Table 34 (Contd.)

Species	Family	Localities B	E	K
Peristrophe bicalyculata	(Acanthaceae)	+	-	-
Spergula arvensis	(Caryophyllaceae)	+	-	+
Tinospora sp.	(Menispermarceae)	+	-	-
Balanites roxburghii	(Simarubaceae)	-	-	+
Grewia oppositifolia	(Tiliaceae)	-	-	+
Bougainvillea spectabilis	(Nyctaginaceae)	-	-	+
Zizyphus nummularia	(Rhemnaceae)	-	-	+
Musa sp.	(Musaceae)	-	-	+
Dodonaea viscosa	(Sapindaceae)	+	-	+
Ephedra foliata	(Ephedraceae)	+	-	+
Jasminum lumile	(Oleaceae)	+	-	+
Lantana indica	(Verbenaceae)	-	-	+
Lawsonia alba	(Lythraceae)	-	-	+
Bombax malabaricum	(Bombacaceae)	-	-	+
Capparis decidua	(Capparidaceae)	-	-	+
Trianthema pentandra	(Ficoideae)	-	-	+

trap 'B' than in traps 'K' and 'E', the rest of all the species showed the highest catches in trap 'K'. Out of these six species, *A. lasiopygus*, *A. compressus* and *H. seticollis* are greater in number in trap 'B' upto July, but in August and September trap 'E' showed markedly higher catches than 'B'. If chapter third be referred to, it becomes clear that the trap 'E' which has comparatively dry surrounding, becomes more efficient after the onset of monsoon when plenty of vegetation comes up in August. Another point in support of this is *C. pithecus*, which is active only after heavy showers in July, always shows higher catches in 'E' (July to October).

The remaining two species, which show much the same pattern of distribution during the four years, have the highest catches in 'K' and the lowest in 'E'. The analysis of variance worked out on two species namely, *A. lasiopygus* and *C. pithecus* showed very significant results in both cases even at 1% level. Obviously, the distribution of insects even in the same locality is dependent on the flora of the spot and is not at random.

(3) The hours of insect activity during night

To study the particular hours of activity during night to some exactness, four collections have been made in one night once a week in light trap 'B' during 1965. These four periods of night are, 6 P.M. to 9 P.M., 9 P.M. to 12 M.N., 12 M.N. to 3 A.M. and 3 A.M. to 6 A.M. Altogether there are 22 such nights when at least one specimen of any of these species has been caught. The data (Tables 32 and 33 and figures 14A to I) can be examined from various angles. From one angle the period of maximum captures of different species in different months can be compared (figures 14A to I). Obviously this period varies from species to species as well as from month to month. Six species namely, *A. ferruginea*, *H. seticollis*, *A. ruficapilla*, *C. pithecus*, *S. ruficollis* and *A. lasiopygus* have appeared in the maximum numbers from 9 PM to 12 MN. The maximum catch of *A. insanabilis* is in the first period (6 PM to 9 PM) and that of *A. compressus* in third period (12 MN to 3 AM). Four species namely, *A. insanabilis*, *A. ferruginea*, *A. ruficapilla* and *A. lasiopygus* have captures above 25% in each of the first and second periods. Two species namely, *A. compressus* and *S. ruficollis* have captures above 25% in each of the second and third periods, whereas the rest of the two species have captures above 25% only in the second period. There are only two species namely, *C. pithecus* and *A. lasiopygus* which show more than 50% captures in the second period.

From another angle the data can be examined for the maximum activity of these species collectively. When the total number of insects captured is added up and the percentages of these that has been caught at the different periods of the night is considered, the period from 9 PM to 12 MN is found to have captured the highest percentage (45.04%). During other periods the respective percentages are, 20.17%, 23.54% and 11.24% from 6 PM to 9 PM, 12 MN to 3 AM and 3 AM to 6 AM (figure 14A).

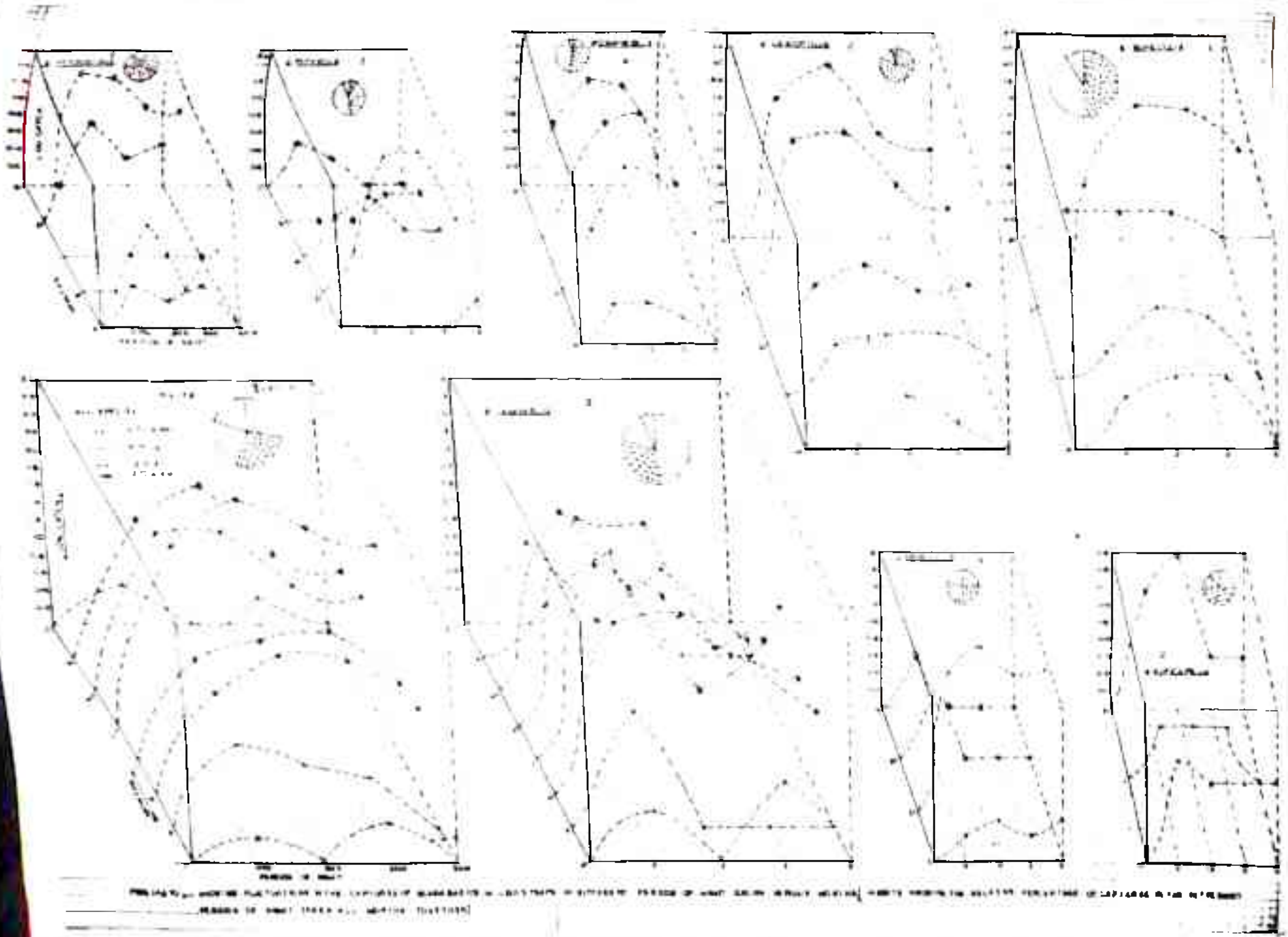


Fig. 14A to I. Showing fluctuations in the captures of Scarabaeids in light traps in different periods of night during various months (inserts showing the relative percentage of captures in the different periods of night taken all months together)

TABLE 32

Total captures of each species during 4 periods of night in light trap 'B'

Species	9 PM	12 MN	3 AM	6 AM
S. ruficollis	28	239	175	60
A. lasiopygus	101	181	37	23
H. seticollis	43	77	47	42
A. ferruginea	61	64	22	22
A. compressus	11	47	56	7
A. insanabilis	49	31	15	8
C. pithecus	5	31	10	5
A. ruficapilla	7	11	4	3
Total	305	681	356	170
Percentage	20.17	45.04	23.54	11.24

(While obtaining log. values, 1 is added to all monthly figures)

TABLE 33

Total captures of all species in each month during 4 periods of night in light trap 'B'

Months	9 PM	12 MN	3 AM	6 AM
March	1	0	2	0
April	9	5	3	0
May	16	41	38	10
June	18	28	32	7
July	145	419	246	131
August	74	78	18	12
September	40	110	16	10
October	2	0	1	0
Total	305	681	356	170

When the captures are studied monthwise the maximum is in the second period during May, July, August and September, in the first period during April and in the third period in June. In March and October only a few specimens have been caught. The possible reasons for such variations in the activity during various periods in different months will be discussed in next chapter.

CHAPTER VII

DISCUSSION

This investigation is an attempt to examine some aspects of the relationships between the captures of 8 species of scarabaeids in light-traps and the conditions which might influence the abundance of their captures. The factors which might govern the abundances of their captures are likely to be very varied. Here the influence of a few of such possible factors has been examined. These factors are:

(1) daily mean temperature
(2) daily mean relative humidity
(3) amount of rainfall
(4) location of the trap
(5) the period of the night and
(6) biology of these insects.

The definitions of these factors have already been laid down (vide chapter III). Following are the salient features of the finding.

(1) The effect of temperature is very specific. Out of eight species, four species show negative relationship, one species shows positive relationship, while the rest do not show any causal relationship with the temperature.

(2) The effect of humidity is different. Here seven species show positive relationship while one shows insignificant

negative relationship. Further, the species which are negatively correlated with temperature show high degree of positive correlation with humidity. Thus *A. lasiopygus*, *C. ruficollis*, *C. pithecus* and *A. ruficapilla* show negative correlation with temperature but high positive correlations with humidity.

(3) Generally, the captures are positively influenced by rainfall.

(4) The vegetation of local sub-pockets (the area surrounding the traps) leave their imprints upon the captures.

(5) The time of flights of each species has a characteristic period of its own. The peaks of activities within a night varies according to species as well as seasons.

(6) Continuous operation of light trap for a period of years may help to investigate the biology of any species abundant in a particular area.

(1) The effect of mean temperature on the captures

The positive effect of temperature on the activity of insects has been observed by several workers, especially in temperate climates. This has been particularly observed in case of various species of moths by Marchal (1912), Yothers (1926-1927), Collins (1929), Parrott and Collins (1934) and Stirrett and Beal (1938). These observations show that the moths are generally very active between 65°F to 70°F (18.3 to 21.1°C). But Hussain et al. (1934) working with *Platyedra* gossypiella in Punjab (India) has found that the most favourable temperature for the activity is between 76°F to 87°F (24.4°C to 30.5°C) and not as low as in the earlier cases i.e. 65 to 70°F.

In the present work it has been observed that the captures of scarabaeids in light-trap are also influenced by temperature. However, the degree of influence of temperature (on captures) vary from species to species (Chapter VI). Generally, the correlations of log. catch of most species with mean temperature are either negative or only insignificantly positive. When arranged in a descending order of negative relationship, S. ruficollis tops the list. The other end of the scale is occupied by A. insanabilis which is the only species in this series that shows a positive relationship. Following is the order:

Species	Regression value for 1°C change in mean temperature
S. ruficollis	-.3015
A. lasiopygus	-.1624
C. pithecus	-.1550
A. ruficapilla	-.1502
A. compressus	-.1000
H. seticollis	no regression
A. ferruginea	no regression
A. insanabilis	+.0426

The above table indicates that the catch of S. ruficollis is halved by increase of 1°C in mean temperature and that of A. insanabilis is doubled by an increase of 7.5°C in mean temperature.

Mukherjee (1956-1959) while working with light-trap captures has also shown that in summer higher maximum temperature (101.7°F or 38.7°C) has adversely affected the activity of lepidopteran pests at Chinsura (West Bengal). The negative regression value indicates a halving of the catch for the rise of 5.8°F in the maximum temperature. Similar observations have been made by Williams and Osman (1960) who obtained negative regressions in summer months on the catches of dipteran in Egypt. Following are the similarities between the observations made here and those of Williams and Osman in Egypt. (1) The mid-day temperature in summer at both places frequently rises above 40°C. (2) The optimum temperature for the highest captures of dipteran, studied in Egypt, is 29.5°C, whereas the optimum temperature for the peak activity of scarabaeids studied here falls between 29.5°C to 30.5°C, although the scarabaeids are active at mean temperatures between 17°C to 37°C. (3) The regression values from May to August at both these places are negative. El-Ziady and Osman (1961) has also observed negative regression coefficients during the summer months of 1957 at Cairo, though the values are not significant (-.006 and -.027). On the other hand Williams' observations at Rothamsted in England (1939-40) are somewhat different from the present investigation.

Unlike Chinsura and Pilani, at Rothamsted the correlations and regressions for log. catch on maximum temperature of the previous day are positive in all the seasons. Following table dealing with the captures at Rothamsted, Chinsura and Pilani will illustrate this.

Rothamsted		Chinsura		Pilani	
Corr.	Reg.	Corr.	Reg.	Corr.	Reg.
0.240	0.042	-.305	-.051	-.8427	-.301

These two groups of apparently contradictory observations require clarification. When the meteorological conditions of these places are compared, it is found that except Rothamsted the other places have broadly similar features. Here are the climographs of these places (Fig. 15) based on monthly means of temperature and amount of precipitation. At Rothamsted the temperature has a range of -21°C to 30.5°C whereas in Pilani the range is from -5°C to 47°C. It has also been showed in the present investigation that the activity of those species which appear in March increases with rising temperature till the middle of April after which the activity declines but again rises towards the end of the period i.e. in August/ September till they disappear from the captures in October. Thus from the present findings it appears that once the temperature is high enough for the flight of the insect, further increase in temperature does not encourage the increase in flight. As a further extension of this idea it can be said that at Rothamsted the temperature during most of the year is lower than the level which is necessary to maintain a cold-blooded animal in activity. On the other hand, the temperature at other three places i.e. Pilani, Egypt and Chinsura, during most of the year, is above the minimum level required for the activity of the insects. In this connection Taylor's view (1963) is noteworthy. While working with the aerial population

Fig. 153 Average temperature and rainfall of [illegible] compared with those of Rothamsted, Egypt and China [illegible]

Fig. [illegible] Showing the comparison between temperature and rainfall at Fiji [illegible] during the years [illegible] to [illegible].

TABLE 35

The average mean temperatures (^{o}F) and rainfalls (inches) at Rothamsted, Pilani and Chinsura

Month	Rothamsted	Pilani		Chinsura	
	50 Years	Difference	8 years	Difference	75 years
			Mean temperature ^{o}F		
Jan.	37.7	+18.6	56.3	+1.5	54.8
Feb.	38.1	+25.7	63.8	+5.1	58.7
Mar.	41.4	+31.4	72.5	+4.7	67.8
Apr.	45.5	+36.6	82.1	+6.9	75.2
May	[illegible]	+36.9	89.4	+11.7	77.7
June	57.2	+37.2	94.4	+15.6	78.8
July	60.7	+28.5	89.2	+10.3	78.9
Aug.	59.9	+26.1	86.0	+7.1	78.9
Sep.	55.8	+28.4	84.2	+5.7	78.5
Oct.	48.9	+29.3	78.2	+3.9	74.3
Nov.	42.3	+24.1	66.4	+2.5	63.9
Dec.	38.8	+18.4	57.2	+1.2	56.0
			Rainfall inches per month		
Jan.	2.427	-2.3139	0.1131	-0.3369	0.45
Feb.	1.910	-1.7384	0.1716	-1.0184	1.19
Mar.	1.992	-1.7034	0.2886	-1.1414	1.43
Apr.	1.985	-1.8797	0.1053	-1.9247	2.03
May	2.152	-1.2745	0.8775	-4.6625	5.54
June	2.243	-1.5098	0.7332	-9.2068	9.94
July	2.640	+3.4011	6.0411	-7.1289	13.17
Aug.	2.659	+2.6762	5.3352	-6.4948	11.83
Sep.	2.391	-0.6750	1.7160	-6.9040	8.62
Oct.	3.059	-2.7977	0.2613	-3.2587	3.52
Nov.	2.701	-2.5099	0.1911	-0.7589	0.95
Dec.	2.637	-2.5590	0.0780	-0.0920	0.17
Total	28.72		15.9120		58.84

of macrolepidoptera, he observed that once the temperature is high enough to allow the insect to generate enough energy to maintain flight, flight activity becomes relatively independent of further rise in temperature. The present investigation shows that once the species is enough active, further increase in temperature leads to negative effect. This is quite obvious from the figures 1d to 8d (Chapter VI) that the high peaks of temperature have always coincided with peaks of low activity. Now looking back into the observations on vine moths and codling moths by Marchal, Yothers and others and on Platyedra gossypiella by Hussain et al. an explanation is put forward for the differences in the ranges of the favourable temperature for activity between these. The observations of the earlier workers are confined to places situated far north of Punjab. Hence, in temperate zones the favourable temperature for activity falls between 65°F to 70°F. But in the sub-tropical zones such as Punjab between 76°F to 87°F (equivalent to the favourable temperature for the present species) depending upon the species as well as on the latitude of the place.

Thus it appears that in temperate and cold places, the flight activity of insects is more dependent on temperature than in tropical and warm climates. This is also agreed upon by Williams (personal communication, 1968). The negative influence of high temperatures on flights at warm climates, will be further discussed in connection with discussion on the effect of humidity (vide infra).

(2) Effect of mean relative humidity

The present investigation shows that the captures of all species except A. compressus are positively correlated with humidity. Four species namely, S. ruficollis, A. lasiopygus, C. pithecus and A. ruficapilla show high regression coefficients significant at 1% level. The highest regression coefficient is .0523, shown by S. ruficollis which means the catch is doubled by an increase of 6% relative humidity (synoptic table 17). Thus it is observed that once a species starts appearing in the trap its further activity and abundance is mainly dependent on relative humidity. This phrase "once a species starts appearing" needs qualification. An insect won't fly unless the temperature is at its minimum threshold level. Once this threshold is reached scarabaeids would fly. But the intensity of their flight then is found to be regulated by the relative humidity. According to Williams (1940) for the whole year, 1% increase in relative humidity would lead to an increase of catch by .0078. This is just significantly positive at 5% level and not at 2%. Broadbent (1947) has observed negative values with Aphididae even at 5% level. Walloff (1953) found that the flight of Schistocerca gregaria in eastern Africa is intermittent with high saturation deficit, but continuous with low saturation deficit.

According to El-Ziady and Osman (1961) the flight activity of night flying dipteran in Egypt is positively correlated with relative humidity except in the autumn of 1955 and in the summer of both years. Mukherjee (1956-1959) has studied the effect of relative humidity on lepidopteran pests at Chinsura. He concludes that the regression values are low. In summer the relation is positive but in rainy season the catch shown negative correlation with humidity. Kundu et al. (1961) having observed one season's monsoon captures conclude that the captures depend considerably upon relative humidity.

In order to understand these apparently confusing and somewhat contradictory observations, the relationships between the temperature of air, relative humidity and the saturation deficit of air is to take notice of. Air can hold a limited amount of water vapour at a particular temperature. The capacity of holding water increases along with rising temperature. If the temperature of a volume of air increases but not the amount of water then the relative humidity goes down. This means the evaporation power of that volume of air goes up. As a result of this physical condition the effect of relative humidity of air in different countries differ. In other words the saturation deficit of air at the same relative humidity but different temperature is enormously different. Insects are very sensitive to saturation deficit or evaporative power of the air. In warm climate like Pilani, changes in relative humidity lead to substantial changes in the evaporative power of the air. On the other hand in a cold place like Rothamsted the corresponding changes in relative humidity can only create a lesser difference in saturation deficit. Moreover owing to low temperature, frequent rains etc. the level of relative humidity at Rothamsted is always high. The following table gives a comparison between the relative humidities of some nights of good captures and nights of poor captures at Rothamsted, Pilani and Chinsura.

TABLE 36

Conditions of Relative Humidity in nights of high and low catches at Rothamsted, Pilani and Chinsura

Rothamsted			Pilani			Chinsura
Year	Min. Prev. Day	Max.	Year	Min. Prev. Day	Max.	Mean
Best nights						
1934	58	90	1964	75.0	84.3	80.4
1935	62	94	1965	52.0	72.0	81.2
1936	75	97	1966	75.0	84.0	81.2
Worst night						
1934	62	95	1964	14.5	32.3	77.7
1935	60	95	1965	20.4	41.6	78.1
1936	71	97	1966	11.0	26.7	81.1
Difference						
1934	-4	-5	1964	+60.5	+52.0	+2.7
1935	+2	-1	1965	+31.6	+30.4	+3.1
1936	+4	0	1966	+64.0	+57.3	+0.1

It is clear from the above table, that the relative humidity is high in both types of nights at Rothamsted. But at Pilani the fluctuations between the saturation deficit of the nights of good and nights of bad captures are enormous. That is why the highly significant positive correlations between the captures and relative humidity are obtained in this work. But not so at Rothamsted. The varying results obtained by other workers at other places can very likely be explained from the point of view of saturation deficit of air in the nights of captures of those places.

(3) The effect of rainfall

The present investigation shows that the rainfall has positive effect on the captures of these scarabaeids (chapter VI). The observations on a few nights of captures during 1964, which is the year of highest rainfall and the highest captures, indicate that there is an increase in the log. catch by .3169 with an increase of rainfall by 6.3 mms. On such nights the mean temperature is approximately 1°C less and the relative humidity increases by 8%. This value is approximately equal with the findings of the effect of temperature and humidity in the case of *S. ruficollis*.

It has been observed in the preceding chapter that the distribution of captures is according to the amount of rainfall during four years. On the basis of yearly changes in amount of rainfall and log. catch, it is observed that an increase of 5 mms in rainfall is associated with an increase of log. catch by .066. Secondly, four species namely, *S. ruficollis*, *C. pithecus*, *A. lasiopygus* and *A. ruficapilla* which prefer the high humidity are the most abundant during 1964 (the year of

TABLE 37

Season-wise mean temperature (^{o}F) and rainfall (inches) at Rothamsted, Egypt, Chinsura and Pilani

	Rothamsted	Egypt	Chinsura	Pilani
		Temperature		
Spring	46.5	66.9	73.6	81.3
Summer	59.3	80.1	78.9	89.9
Autumn	49.0	70.7	72.2	76.3
Winter	38.2	54.3	56.5	59.1
		Rainfall		
Spring	2.043	0.0906	3.11	0.4238
Summer	2.514	0.0118	11.65	4.0365
Autumn	2.717	0.0906	4.36	0.7228
Winter	2.325	0.1457	0.60	0.1209

TABLE 38

Monthly mean percentage relative humidity at Chinsura and Pilani

Month	Chinsura	Difference	Pilani
Jan.	60.3	-13.01	47.29
Feb.	54.0	-10.76	43.24
Mar.	49.6	-17.13	32.47
Apr.	53.7	-28.59	25.11
May	65.0	-39.86	25.14
June	76.0	-40.20	35.80
July	82.8	-22.71	60.09
Aug.	82.9	-13.05	69.85
Sep.	81.7	-20.07	61.63
Oct.	75.7	-32.45	43.25
Nov.	68.0	-23.85	44.15
Dec.	62.5	-19.95	42.55

the highest rainfall, 520 mms). Moreover, the abundance of these species in captures is found to be related with amount of rainfall.

The importance of rainfall has also been mentioned by Williams (1940) who observes that during summer months rainfall is most important and temperature changes can be neglected. But Mukherjee (1956-1959) at Chinsura has observed that average day rain amounting to 0.34 to 0.56 inches affect the activity adversely. A comparison of the climographs (figure 15) of these places reveals that Chinsura is as much as three times wet as compared to Pilani. Thus it appears that the humidity at Chinsura during monsoon is too high to have any positive effect on the captures of insects. At Pilani the rainfall is scanty and scattered and the temperature is high. Hence, the fluctuations in humidity in monsoon at Pilani are reflected upon the captures.

(4) Location of the trap

A comparison of the captures of the different traps with each other shows that, throughout the period of study, the captures of each trap are significantly different from the other two traps (even at 1% level). This has been assessed with analysis of variance.

All the 3 traps are located within an area of 1 square mile (although away from the sphere of influence of each other). Still, the flora around each trap are substantially different from those around other traps. The vegetation around trap 'K' is most prolific and varied while those around 'E' is sparse. Trap 'B' has somewhat intermediate condition (Table 34).

Figure 13 shows the locations and the following table summarizes the results of the analysis of variance of the captures of one species. The details of this analysis are presented in Tables 30 and 31.

Source of variation	Amount of variation	Degree of freedom	Estimated variance
Between column means	462556.3	2	231278.1
Within columns	1209621.4	57	21221.8

$$F = \frac{231278.1}{21221.8} = 10.8$$

The probability of getting $F > 10.9$ is much less than .001 or .1% with $n_1 = 2$ and $n_2 = 57$ degrees of freedom. Hence, there is a real difference between the catches of three traps. Following are the observations:

(1) Among the three locations where various traps have been operated, location of trap 'K' is found to be best for high catches (58.3%). The trap 'E' with comparatively sparse vegetation becomes more efficient only after the onset of monsoon, when plenty of vegetations come up.

(2) It has been observed that differences in locality are specific and it is not necessary if a particular locality is good for one species should be the same for another. For example <u>S. ruficollis</u> and <u>A. ruficapilla</u> have always

preferred 'B' while the rest of the species prefer location 'K'. The percentages of these two species in trap 'B' are 50.2% and 45.4% respectively.

Williams (1951) while comparing the efficiency of various traps has observed that some variance in the catches may be due to the surrounding vegetations. He has concluded that there are considerable differences between localities, as all the traps show preferably high catches at a particular position (location 'C' in his work). Further he points out that the noctuid moth Cerapteryx graminis shows a definite location difference. 92 individuals of this have been caught, and all except 2 are in location 'C'.

Thus it is concluded that this difference in the flora has contributed towards the differences in the captures.

(5) The hours of insect activity during the night

The hour of the night when insects are caught in largest numbers in the trap can be called the period of maximum flight activity. This period of maximum flight activity varies from species to species as well as from month to month.

Each species has a characteristic peak of activity in the night. Some are trapped in larger numbers in the first period (6 to 9 PM), as compared to other periods, while the same may not be true for other species. Some species such as A. lasiopygus, S. ruficollis, C. pithecus, H. seticollis and A. ferruginea appear in largest numbers during 9 to 12 MN (second period). The percentage of each species that is captured in any particular period of the night has been found to be quite different from other periods as indicated in the inserts in the figures 14A to i.

Further, when the captures are studied monthwise, it has been found that all the species except A. lasiopygus and S. ruficollis, show the peaks of activity in different hours of night in different months. Whereas A. lasiopygus and S. ruficollis show the peaks of activity in the second period of night during all the months (figures 14H and i).

It appears reasonable to assume that the stimulus to flying for an insect in the night is associated primarily with the prevailing temperature and humidity. It may be noted that A. insanabilis is the only species among these scarabaeids which shows positive correlation with temperature. That may be the reason for this species being caught in large numbers in the early hours of evening when the air is warm. A. compressus which is the most active during summer (May and June), has preferred to come during the third period of night when the night is cooler. It has been already mentioned elsewhere (Chapter VI) that this species shows insignificantly negative correlation with temperature. The same argument holds good to explain the fluctuations in captures in different months as well.

Williams while studying the total captures of light trap (1939) found that the captures are the highest in the first part of the night while least in the seventh part (he however, divided the whole night into eight equal parts).

England, where Williams worked is much colder than Pilani, hence the maximum catches of insects there are mostly confined in the early parts of the night. Mukherjee (1956-1959), on a study with certain lepidopteran pests, observes that in winter the captures are higher in the first part of the night but in summer when the maximum day temperature is quite high even the early flyers have appeared late in the night (he, however, divided the night into three equal parts). In summer the early part of night might have been too warm for those lepidopteran.

Thus on the whole the present findings confirm those of Williams on insects in general and Mukherjee on lepidopteran pests in particular. Here during May, June and July the percentage captures of scarabs is higher in the third period than the first period. During April, August and September the captures are more in the first period than the third period. The possible explanation for these observations may be that during summer months, due to high temperature, warm conditions prevail upto the first few hours of the night which has affected the activity in the first period. Whereas during April, August and September when the temperature is comparatively low, first period is more favourable for activity (figure 14A). However, these scarabaeids are mostly susceptible to drought and hence limited to summer and monsoon only, hence do not appear in captures in winter. The lepidopteran studied by Mukherjee are abundant in winter as well. Therefore, these differences in the hours of flight activity of insects are mainly due to the temperature prevailing at those hours.

(6) Relationship between the biology of these species and their captures in light traps

From Chapter V, it is concluded that scarabaeids show considerable variations in their biology depending upon place, availability of food and other seasonal changes. They are largely phytophagous and saprophagous. The family includes both nocturnal and diurnal species. The life cycles range from 1 to 11 years and the larvae of many scarabaeids live mostly in the soil. Perhaps all these factors have contributed towards the paucity of information regarding the emergence and periods of flights of Indian scarabaeids in comparison with, for example, Indian cerambycids. Quite a lot of information on the emergence and the factors which govern it are available on cerambycids - Hoplocerambyx spinicornis, Stromatium barbatum etc. but this is not so with Scarabaeids. In fact, according to Maxwell-Lefroy (1909) the life history of no Indian Melolonthidae is recorded in any detail.

However, Beeson (1941) has summarised the then available information on the forest scarabaeids of India. According to him, S. ruficollis starts defoliating at the beginning of rains and lives only for over one month. A. ferruginea defoliates some forest trees during June and July. H. seticollis swarms at the beginning of monsoon and defoliates various trees. Adoretus is also a defoliator in its adult stage. A. lasiopygus lives only for about a month after the hatching of eggs in July. With regards to Anomala ruficapilla, Beeson has not given any indication of the time of swarming although many of the other species of the genus swarm during June and July.

According to Maxwell-Lefroy (1909), *Catharsius molossus* (a related species) is common in the plains of India and come freely to lights in the rains, he however said nothing about *C. pithecus*. *Schizonycha xanthodera* (a related species) comes freely to light during rains. *Anomala varians* (another related species) pupates in soil in March, April or May and emerges after 10 days. The life history occupies 1 year.

According to Stebbing (1914), *Anomala grandis* (a related species) was found stripping the leaves in June at elevations of 5000 to 6000 ft. in Darjeeling forest. *Adoretus caliginosus* (a related species) defoliates trees in first half of May.

Melolonthinae

When the present observations are compared with those of Beeson, it is found that the periods of flight of all the melolonthines studied here are much longer than the periods of defoliation caused by these beetles. Following is the comparison:

Species	Period of defoliation Beeson (1941)	Period of flight in present investigation.
S. ruficollis	One month (at the beginning of the rains)	May to August (peak - July and August)
H. seticollis	Same	May to October (peak - July)
A. ferruginea	June and July	March to October (peak - July)
A. insanabilis	No observation	Same

This difference may be explained at least partially by the following points.

Either Beeson has considered only the peak periods of their activity as economically important and hence took only that period into consideration or the periods of defoliation occupy only a part of the period of flight activity of these insects. Further, there may be a genuine difference between the periods of activity at Pilani and those of elsewhere. Similarly, following are comparison of the flight activity of scarabaeids studied here and with the activity of same species elsewhere.

Rutelinae

Species	Period of defoliation Beeson (1941)	Period of flight in present investigation
A. lasiopygus	One month (after the rains have set in)	May to October (peak - middle of Sep. to middle of October)
A. compressus	No observation	April to August (peak - May)
A. ruficapilla	June and July	May to July (peak - July)

The reasons put forward to explain the captures of Melolonthinae should hold true for rutelines as well.

Coprinae

Species	Period of defoliation Beeson (1941)	Period of flight in present investigation
C. pithecus	No observation	June to October (peak - July)

It is also noted that according to Beeson, June is the month of the highest activity for *A. ferruginea* but from the light trap captures it has been observed that it is most active in the month of July. The possible reason may be that June in Pilani is both hot and dry whereas in Dehra Dun the rains have already set in. In this connection it may be worth mentioning Beeson's observations on *Hoplocerambyx spinicornis* that the emergence of this species does not start until the first monsoon showers occur and that the subsequent peaks of beetle emergence coincide with peaks of rainfall. Again *S. ruficollis* whose captures are positively correlated with humidity (regression value .0523) shows peaks of activity in most humid months (July and August). This is true for all the species studied here except, *A. compressus* which is abundant in May and does not show positive correlation with humidity and light trap captures.

From the above tables it is clear that the peaks of activity of the two species of the same genus (*Adoretus*) can fall widely apart. *A. lasiopygus* has the peak in August/

September whereas the peak period of activity (captures) of A. compressus is in May. Climate of May is substantially different from that of August/September. Further it has been already mentioned that the biology of a species at one place may be substantially different from the biology of the same species at another place.

(7) A calendar of the flights of these scarabaeids

Species		Mar.	Apr.	May.	June	July	Aug.	Sep.	Oct.
Autoserica	A. insanabilis	+	+	+	+	Peak	+	+	+
Apogonia	A. ferruginea	+	+	+	+	Peak	+	+	+
Holotrichia	seticollis	-	-	+	+	Peak	+	+	+
Schizonycha	ruficollis	-	-	+	+	Peak	+	+	-
Catharsius	pithecus	-	-	+	+	Peak	+	+	-
Anomala	ruficapilla	-	-	+	+	Peak	+	-	-
Adoretus lasiopygus		-	-	+	+	+	Peak	+	+
Adoretus compressus		-	+	Peak	+	+	+	-	-

A calendar of captures of these scarabaeids can be a valuable guide to the economic entomologists. The measures to control these insects can be more efficiently used when the months and peaks of the flights are well established.

(8) Continuous operation of light traps and depletion of insects

There is no evidence that the continuous operation of light traps has affected the size of the natural population of these beetles. Because in many instances the captures in later years are more than the earlier years, although, the trapping was continuous. This is true both on the basis of total collection as well as on species basis. For example, during 1966 which is the fourth year of the operation of the light traps, the total catch is more than the preceding year. Secondly, three species namely, A. compressus, A. ferruginea and H. seticollis show higher catches during 1965 as compared to preceding two years. A. lasiopygus has more catch during 1966 than 1965. S. ruficollis and C. pithecus have more than double the catches in 1966 as compared to 1963. A. insanabilis shows the highest captures during 1966 out of all the four years.

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SUMMARY

The present work deals with daily captures of 8 species of scarabaeids for 4 years in 3 light traps at Pilani (Rajasthan).

A summary of the daily weather data of Pilani for 4 years (1963-1966) has been prepared and the climate of Pilani has been compared graphically with those of Rothamsted, Egypt and Chinsura - the places where similar studies have been conducted.

The effects of certain environmental factors upon the abundance of captures have been examined.

1. The temperature of air influences the captures markedly. The abundance of 4 species namely, S. ruficollis, A. lasiopygus, C. pithecus and A. ruficapilla in the trap is negatively correlated with temperature. Amongst these, S. ruficollis shows the highest negative response (regression value -.3015). This means that the catch of S. ruficollis is halved per degree rise in mean temperature. A. insanabilis shows positive correlation, while the rest of the species do not show significant correlations.

2. With regard to mean relative humidity of the air, except A. compressus, the captures of all the other species are positively correlated. Similar to temperature, the effect of relative humidity is highly significant in the

case of 4 species namely, *S. ruficollis*, *A. lasiopygus*, *L. pithecus* and *A. ruficapilla*. Amongst these, *S. ruficollis* shows the highest positive response (regression value .0523). This means the catch of *S. ruficollis* is doubled by an increase of 6% relative humidity.

3. The rainfall has positive effect on captures. A comparison of the annual captures with annual rainfall shows that an increase of 5 mms in rainfall is associated with an increase in log. catch by .066. Briefly, the abundance and distribution of these scarabaeids in light traps is found to be related to the distribution and amount of rainfall in these years.

4. The flora surrounding each trap influences the captures significantly, although all the traps are located within one square mile area. The trap which is surrounded by flower gardens and other vegetations throughout the year, shows a consistent higher catch in comparison with the trap which is surrounded by sparse vegetation.

5. The period of the night seems to have a bearing on the captures. Generally, the period from 9 PM to 12 MN shows the maximum numbers of scarabaeids. Very likely the peak of flights of a scarabaeid in a night is influenced by the temperature and humidity of the air at that time.

6. The periods of flight of all the scarabaeids are found to be longer than the period of defoliation by the same species as recorded by workers elsewhere.

7. A calendar of the flight activity of insects can be a valuable guide in initiating control measure for these.

8. There is no indication however, that continuous operation of such light traps deplete the endemic fauna.

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