PART-II
(BIONOMICS)

I N T R O D U C T I O N

The use of light trap for controlling night-flying insect pests has long been a conventional practice in various parts of the world. In recent times light trap has been successfully used by various workers in different countries for collecting positively phototropic insects for bionomical studies.

Work done abroad:

The efficacy of light traps in insect survey was convincingly demonstrated by Williams (1923, 1924, 1936, 1939, 1940, 1948, 1951, 1961, 1962 and 1964), and by Williams and Davies (1957) on the basis of extensive trials carried out in Scotland and also in Egypt. Some of these works in Scotland revealed various insect groups in the area, their relative abundance and incidence in a year, variations in their seasonal incidence from year to year, their differential activity in different hours of a night and so on. In England, Smith (1923), de Worms (1930, 1931, 1932 and 1933) and Andrews (1931) also

used light traps primarily for the collection of specimens. Working in the U.S.A., Cook (1921, 1923 and 1930) made a most excellent study on the ecology of Noctuidae (Lepidoptera) largely from trap records.

Frost (1957a, 1962, 1963, 1964a, b) carried out extensive light trap surveys in Florida, Tennessee and in some other parts of the U.S.A. In one of these works Frost (1963) successfully demonstrated the correlation of meteorological conditions to the activity of insects, and explained that a light drizzle hardly affected the incidence of insects, and a foggy weather with drizzle accompanied by high temperature increased the rate of collection, whereas the catch rate waned in heavy rains or in strong winds.

Working in Florida, Beck (1958) reported that it was possible with the help of light trap to survey the population of night-flying insects within a radius of one mile around the trapping site, and it was also possible to determine the relative abundance, seasonal incidence and seasonal succession of the insect species in question.

Snow and Pickard (1954), and Pickard and Snow (1955) undertook extensive light trap surveys of the night biting Diptera in the Tennessee river basin of the U.S.A.

Working in Central Asia, Mazokhin-Porshnyakov (1956) reported a very heavy catch of black flies. In Canada, Fredeen

(1961) demonstrated the suitability of a light trap for testing the attacking behaviour of a black fly. The time of flight of certain nocturnal lepidopteran insects was measured by Hanna (1968) in Egypt by means of a light trap.

Service (1969) published a bionomical note on some Ceratopogonids caught in Southern England with the help of light trap. In Japan, Kurashige (1970) studied the nocturnal succession of mosquitoes with the help of light trap.

Numerous other reports on the light-trapping of different insects in various parts of the world are extant.

Work done in India:

In India, systematic light-trapping for studying insect bionomics was undertaken by Banerjee and Basu (1951). For sampling work these workers (Banerjee and Basu, 1956) devised a standard light trap device which was later used by Sen and Das Gupta (1959) to determine the nocturnal periodicity and by Das Gupta (1961, 1967) to establish the dominant species and the relative abundance of some ceratopogonids in the Gangetic West Bengal. Working in Pilani, Rajasthan, Kundu et al. (1964) recorded the abundance of some insects caught in the light trap. These workers emphasized that the frequency rather than the quantity of rain fall influenced the incidence of insects. Sinharay et al. (1969) working in Darjeeling assessed the abundance and nocturnal periodicity of some phototropic insect

populations by light-trapping. According to these workers cloudy nights with slight precipitation, accompanied by moderate temperature, yielded higher incidence of insects. Chaudhuri (1970) recorded the distribution of some ceratopogonids in Darjeeling and other parts of India with the help of light traps.

The present work was undertaken to assess the efficacy of the light trap in sampling black flies available in Darjeeling and its environs, and also to determine the relative abundance, seasonal incidence, seasonal succession, sex-ratio, internal conditions of females, host preferences, nocturnal periodicity, photophilic behaviour and some other aspects of bionomics of black flies. It will be noted that a comprehensive work on the bionomics of black flies, using light traps, was not previously undertaken in India.

MATERIALS AND METHODS

The imaginal forms of black flies (Simuliidae: Diptera) constituted the study material. These forms were collected by a light trap device operated between 7 P.M. and 5 A.M. during the period April 1 to September 30 for three consecutive years, i.e., 1968, 1969 and 1970, at Darjeeling Government College campus located at an altitude of 2014 metres from the sea-level. The light trap device used in this study did not strictly conform to any particular design reported earlier, such as the New Jersey light trap (Headlee, 1932), Rothamsted light trap (Williams, 1948), Robinson light trap as reported by Williams et al. (1955), Pennsylvania light trap (Frost, 1957b) and the Chinsuralight trap (Banerjee and Basu, 1956).

The light trap used in the present study was based on the essential principles of all these earlier devices.

Description of the light trap and its operation:

The light trap device (Fig.6) was essentially a four-walled chamber (60 cm. x 60 cm.) of plain sheets of tin (B), covered with a slopping roof (R), and open at the bottom.

LIGHT-TRAP DEVICE

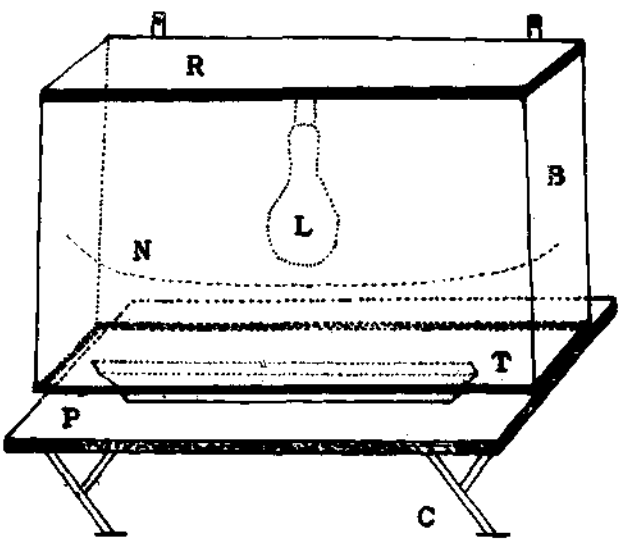

FIG. 6: Diagram of the simple light trap device of the present study

This chamber was fixed to the open terrace, facing north, in the second floor of the building housing Darjeeling Government College. A light source (L) of 500 wattage having a reflecting top-cover (not shown in the figure) was placed at about the middle of the open end of the chamber, hanging from its roof. An iron-wire netting (N) of 4 mesh per square centimetre was used to protect the light source. About 12 cms. beneath the open end of the chamber there was a platform (P) fixed to the wall with the help of two iron stands (C). A rectangular tray (T) measuring 45 cm. x 36 cm. x 5 cm., containing the trapping liquid layer of 5% aqueous solution of acetic acid to a depth of about 2.5 cms. and covered with an iron-wire netting (not shown in the figure) of 4 mesh per square centimetre was placed on the platform during the operational period.

The trap was switched on at 7 P.M. and switched off at 5 A.M. regularly every day. After night-long trapping the tray of the trap device was brought to the laboratory, and after removing the iron-wire netting fresh water was added to the tray-contents to increase the volume of the liquid. Surplus water thus added served to dilute the solution and took away the corrosive stench of acetic acid making direct collection of trapped black flies from the solution easy. The black flies were then collected in watch glasses containing 90% ethanol, and sorted under a stereoscopic binocular

Trap site and neighbourhood

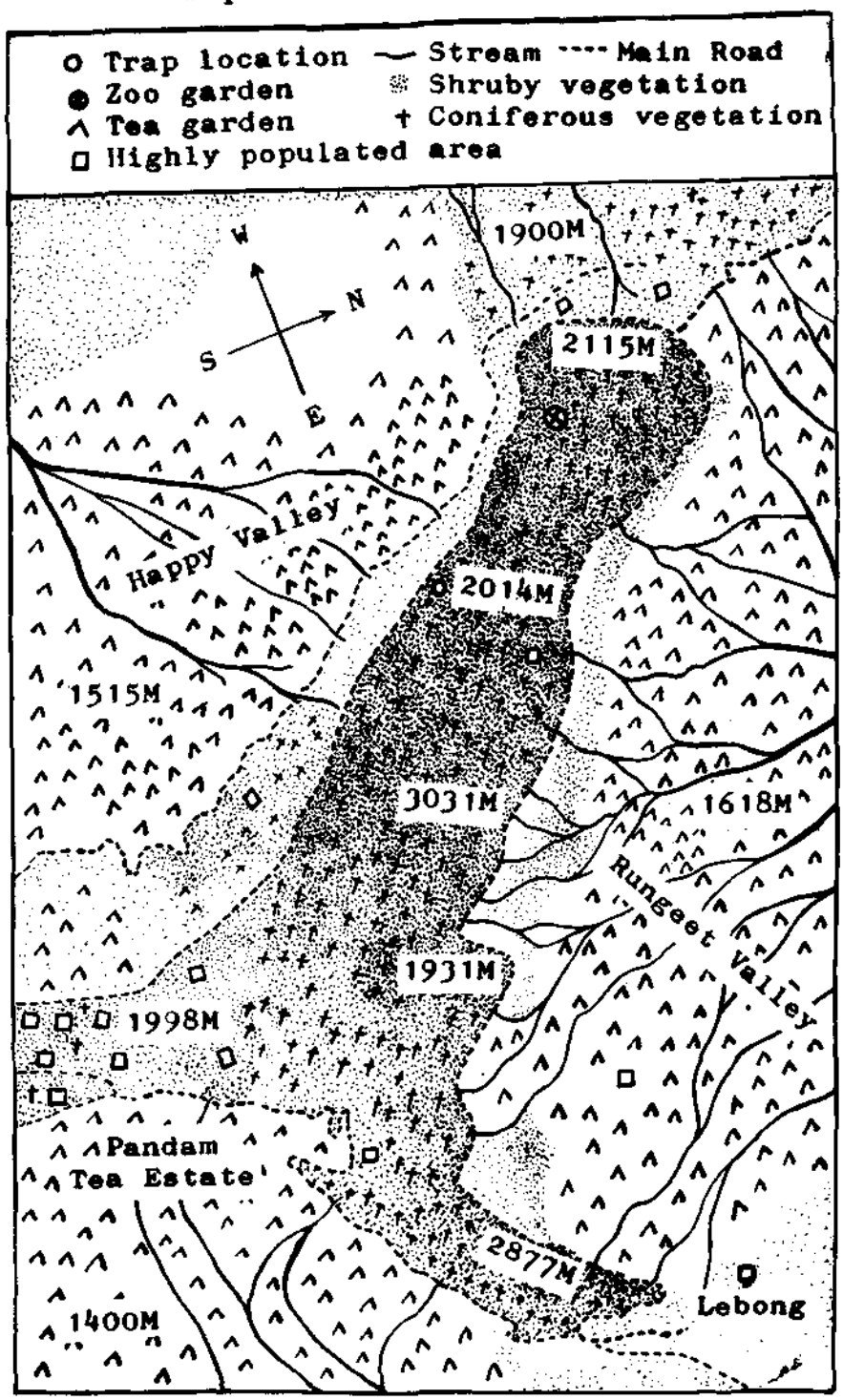

FIG.7: Diagram showing distribution of vegetation, various waterways, residential pockets, altitudinal variations of the terrain of more than one square mile area around the trapping site

FIG.8: North-East Side

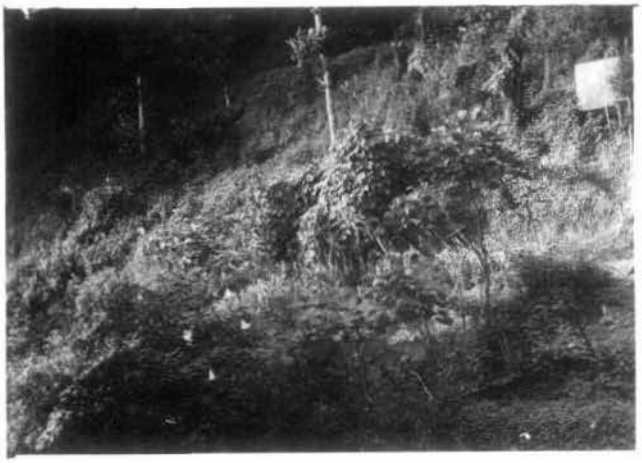

FIG.9: North-West Side

Photographic views of the backside of Darjeeling Government College campus towards the collecting site, showing vegetational covers

microscope, and the details of the catch were duly recorded. Specimens of each species-group were preserved in separate glass tubes or plastic receptacles containing 90% ethanol.

Description of the trapping site:

The campus of Darjeeling Government College which was the trap site for the purpose of this study is situated on a well-forested hill-slope known as Birch Hill (Altitude 2115 m. - 3031 m.) towering at the northern end of the township of Darjeeling (27°3"N latitude and 88°18"E longitude). The terrain is undulating and covered with variegated flora (Figs. 7-9). The altitudinal level of one square mile area around the trapping site ranges from 1515 m. to 3031 m. and the terrain leads much further down to tea estates which border the trapping site. This area is thinly populated and abounds in pockets of water courses which are available as ideal breeding ground for black flies. The forest-clad slope is haunted by flying squirrels (Fam.Sciuridae) at night; and a considerable part of the slope is occupied by the Himalayan Zoological Park, an open air animal park, where tigers, bears, deer, leopards, Tebetan Yaks, and South American llama roam about. Domestic animals which occur in the vicinity, and which may also serve as blood source for black flies, include dogs, cats and cattle. Avian fauna in the Zoological Park includes mainly pheasants and Himalayan passerines.

STUDY OF EFFICACY OF LIGHT TRAP AS SAMPLING DEVICE FOR BLACK FLIES

Introduction

Black flies belonging to the family Simuliidae (Diptera) are positively phototropic (Williams and Davies, 1957), and many workers noticed that the light trap was an effective instrument for sampling these flies. Frost (1949) and Fox (1953) reported that black flies appeared at the trap as the individuals were stimulated to fly after they have settled for the night within the effective range of the trap. Fredeen (1961) experimented with different types of traps and conclusively proved the efficacy of light trap as the sampling device for these flies. Davies and Williams (1962), Davies et al. (1962) and Williams (1962) recorded high numbers and regularity of appearance of black flies at the light trap operated at Kincraig (Scotland).

To extend the above studies to eastern Himalayas the present work was undertaken at Darjeeling.

Method

Black flies were collected by continuous light trapping between 7 P.M. and 5 A.M. at Darjeeling Government College campus in 1790 trap-hours of 179 nights from April 1, 1968 to September 30, 1968; in 1800 trap-hours of 180 nights from April 1, 1969 to September 30, 1969; and in 1810 trap-hours of 181 nights from April 1, 1970 to September 30, 1970, with the help of the simple light trap device described in the page no.132.

Result

Black flies collected by the above method were found to consist of six major species, namely, Simulium (Eusimulium) praelargum, n.sp., S.(E) gracilis, n.sp., Simulium (Simulium) himalayense Puri (1932a), S.(S.) grisescens Brunetti (1911), S.(S.) rufibasis Brunetti (1911) and Simulium (Gomphostilbia) tenuistylum, n.sp., and a few other minor species.

Monthwise collection data for each of the six species represented in 1968, 1969 and 1970 are given separately and in average (Table I-IV).

Table-I

Monthwise assortment of six species of black flies in 1968

Months	*praelargum*	*gracilis*	*himalayense*	*griseescens*	*rufibasis*	*tenuistylum*	Total
April	53	23	69	7	7	9	168
May	135	68	178	8	25	85	499
June	51	25	86	113	114	53	442
July	14	9	52	79	35	6	195
August	7	4	21	43	18	12	105
September	4	2	54	52	77	43	232
TOTAL	264	131	460	302	276	208	1641

Table-II

Monthwise assortment of six species of black flies in 1969

Months	*praelargum*	*gracilis*	*himalayense*	*griseascens*	*rufibasis*	*tenuistylum*	Total
April	60	42	51	3	5	5	166
May	142	97	120	80	10	25	474
June	22	17	70	31	72	64	276
July	23	12	32	20	53	20	160
August	9	12	49	17	14	32	133
September	27	12	31	32	41	27	170
TOTAL	283	192	353	183	195	173	1379

Table-III

Monthwise assortment of six species of black flies in 1970

Months	*praelargum*	*gracilis*	*himalayense*	*grisescens*	*rufibasis*	*tenuistylum*	Total
April	260	171	316	55	142	132	1076
May	171	97	331	49	59	27	734
June	60	34	118	34	106	21	373
July	24	22	64	56	37	17	220
August	37	24	35	30	29	30	185
September	29	17	57	53	49	35	240
TOTAL	581	365	921	277	422	262	2828

Table-IV

Monthwise assortment of six species of black flies in average (1968, 1969 and 1970)

Months	*praelargum*	*gracilis*	*himalayense*	*grisescens*	*rufibasis*	*tenuistylum*	Total
April	124.3	78.7	145.3	21.7	51.3	48.7	470.0
May	149.3	87.3	209.7	45.7	31.3	45.7	569.0
June	44.3	25.4	91.3	59.3	97.3	46.0	363.6
July	20.4	14.3	49.4	51.7	41.7	14.2	191.7
August	17.7	13.3	35.0	30.0	20.3	24.7	141.0
September	20.0	10.3	47.3	45.6	55.8	35.0	214.0
TOTAL	376.0	229.3	578.0	254.0	297.7	214.3	1949.3

Understanding of different bionomical aspects such as relative abundance, seasonal incidence and seasonal succession, sex-ratio, internal conditions of females, host preferences, nocturnal periodicity and photophilic behaviour of these species of black flies, was found possible through proper assessment of the periodic or nightwise catch.

Meteorological conditions such as atmospheric temperature, mean relative humidity, rain fall and wind velocity throughout the whole study period were recorded near the collection site. Correlation of these meteorological conditions to various bionomical aspects of black flies are provided in Tables V-VIII.

Table-V

Monthwise estimation of meteorological data taken near Darjeeling Government College during April 1, 1968 to September 30, 1968

Months	Min. Temperature ('C)		Max. Temperature ('C)		Rel.Humidity (%)		Rainfall (mm.)		Wind Velocity (Km./Hr.)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
April	10-18	12.6	18-26	24.1	46-90	73.3	0.8- 16.0	6.2	2-7	3.2
May	11-20	16.0	20-28	23.7	67-83	74.7	1.0- 18.0	5.9	1-7	3.2
June	13-19	14.9	23-30	26.6	62-91	82.0	0.8- 58.6	17.3	1-9	2.9
July	9-15	13.1	18-29	22.9	81-99	88.9	1.6-102.0	24.7	1-3	2.1
August	15-20	17.6	22-28	24.7	85-96	90.4	0.6- 56.0	18.6	1-6	1.9
September	16-21	18.3	20-26	23.8	77-88	82.1	2.0- 69.8	10.7	1-3	1.8

Table-VI

Monthwise estimation of meteorological data taken near Darjeeling Government College during April 1, 1969 to September 30, 1969

Months	Min. Temperature ('C)		Max. Temperature ('C)		Rel.Humidity (%)		Rainfall (mm.)		Wind Velocity (Km./Hr.)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
April	15-19	16.9	25-29	26.8	57-89	72.4	1.8- 11.8	6.0	1-12	3.4
May	18-23	20.9	27-30	28.9	70-95	84.3	0.8- 16.8	10.6	1- 9	2.8
June	15-19	17.5	22-29	25.6	85-96	92.8	1.8-116.6	24.6	1- 6	2.5
July	13-18	16.3	21-27	24.1	90-95	92.5	1.5- 74.7	25.1	1- 7	1.8
August	14-21	19.5	25-28	26.5	85-95	89.5	1.2- 72.0	21.1	1- 6	2.2
September	19-22	20.4	25-29	26.7	73-93	81.9	1.5-127.0	25.5	1- 9	2.1

Table-VII

Monthwise estimation of meteorological data taken near Darjeeling Government College during April 1, 1970 to September 30, 1970

Months	Min. Temperature ('C)		Max. Temperature ('C)		Rel.Humidity (%)		Rainfall (mm.)		Wind Velocity (Km./Hr.)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
April	12-17	13.3	19-26	23.4	57-73	65.1	1.0- 11.8	5.4	1-8	2.6
May	13-15	14.3	20-26	23.2	70-94	82.8	1.5- 60.0	10.4	1-7	2.5
June	14-18	16.4	21-26	23.8	83-95	89.3	0.8-105.4	23.0	1-9	2.1
July	16-18	16.8	22-26	23.4	77-98	90.1	0.5-136.8	31.9	1-4	2.0
August	15-19	17.4	21-30	23.7	80-90	86.9	0.8- 66.6	15.3	1-4	1.8
September	15-19	17.3	21-27	25.0	81-88	84.1	0.6- 94.0	13.0	2-7	2.8

Table-VIII

Monthwise estimation of meteorological data taken near Darjeeling Government College during the whole study period (in average of 1968,1969 and 1970)

Months	Min. Temperature ('C)		Max. Temperature ('C)		Rel.Humidity (%)		Rainfall (mm.)		Wind Velocity (Km./Hr.)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
April	13-17	14.3	23-26	24.6	61-80	69.8	1.2- 13.2	5.9	1.3-9.0	3.1
May	14-19	17.2	24-27	25.2	71-87	80.7	1.1- 31.6	5.0	1.0-7.6	2.8
June	15-18	16.1	23-27	25.3	78-93	88.1	1.1- 93.2	22.7	1.0-8.0	2.5
July	14-16	15.4	22-25	23.4	87-93	90.4	1.2-104.5	27.2	1.0-4.6	2.0
August	16-20	18.2	23-27	25.0	86-92	89.0	0.9- 61.5	18.3	1.0-5.3	1.9
September	17-20	18.6	23-27	25.1	77-87	81.4	1.3- 96.9	17.0	1.3-6.3	2.2

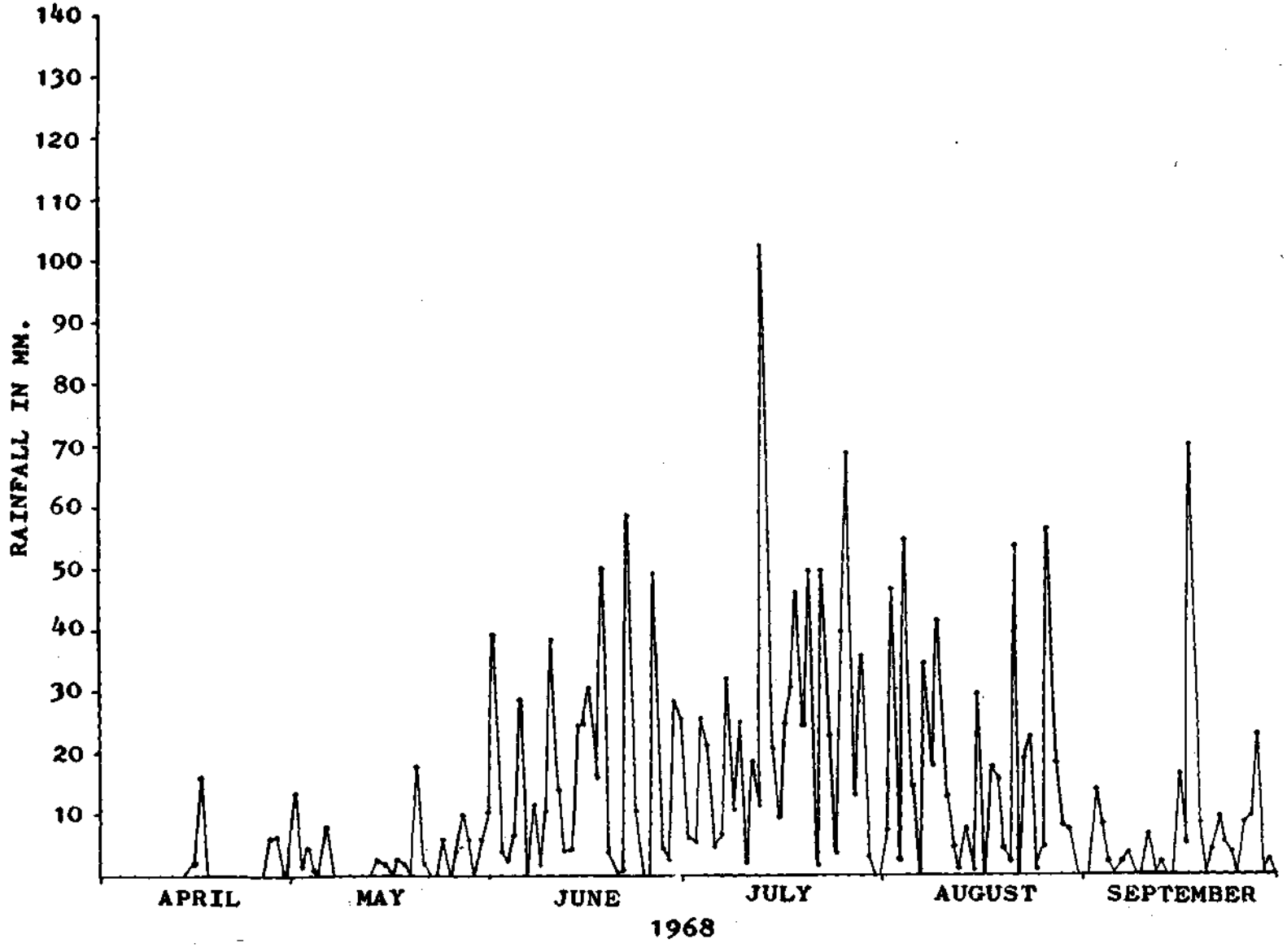

FIG.10: The rainfall in Darjeeling from April 1, 1968 to September 30, 1968

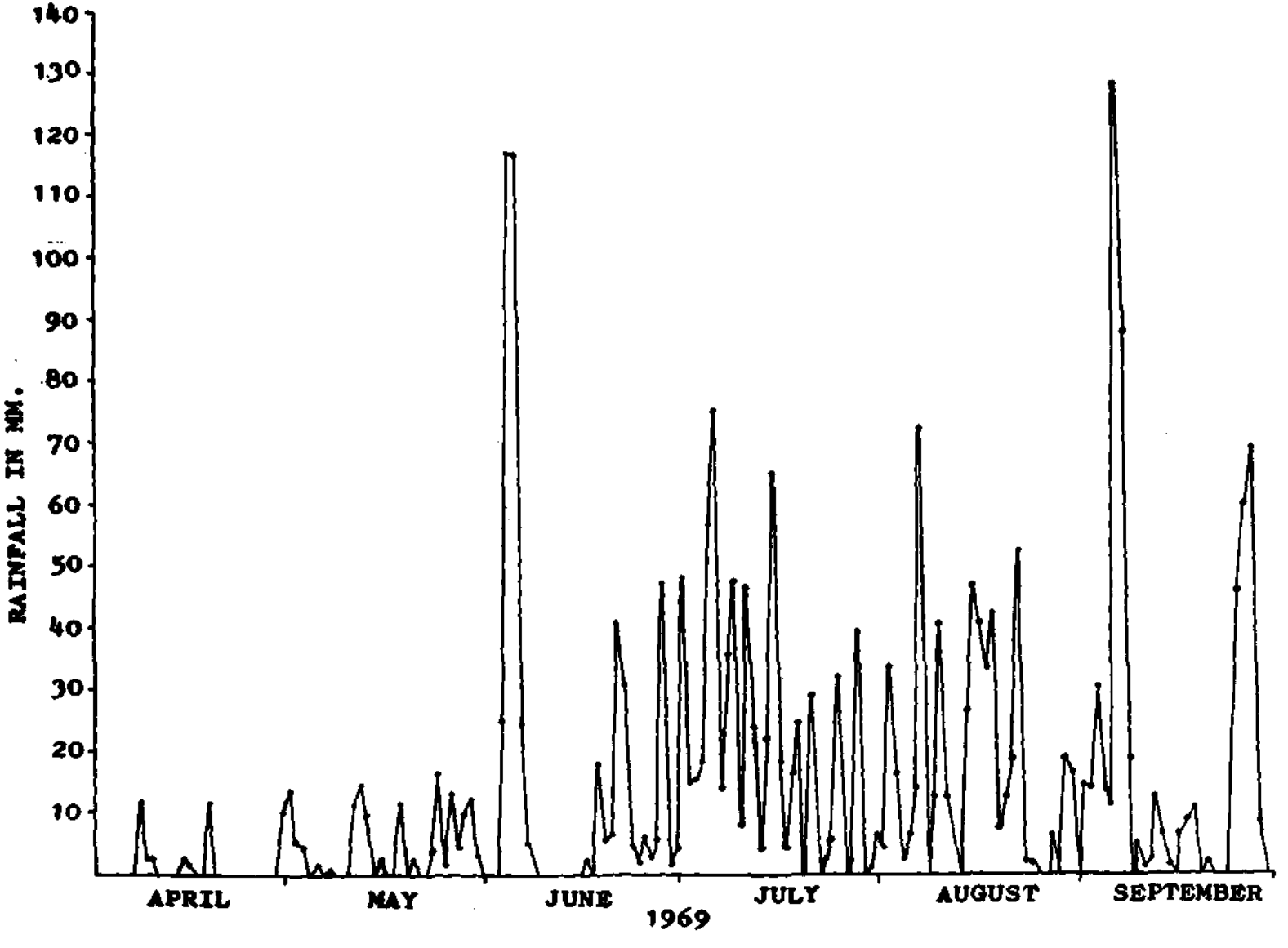

FIG.11: The rainfall in Darjeeling from April 1, 1969 to September 30,1969

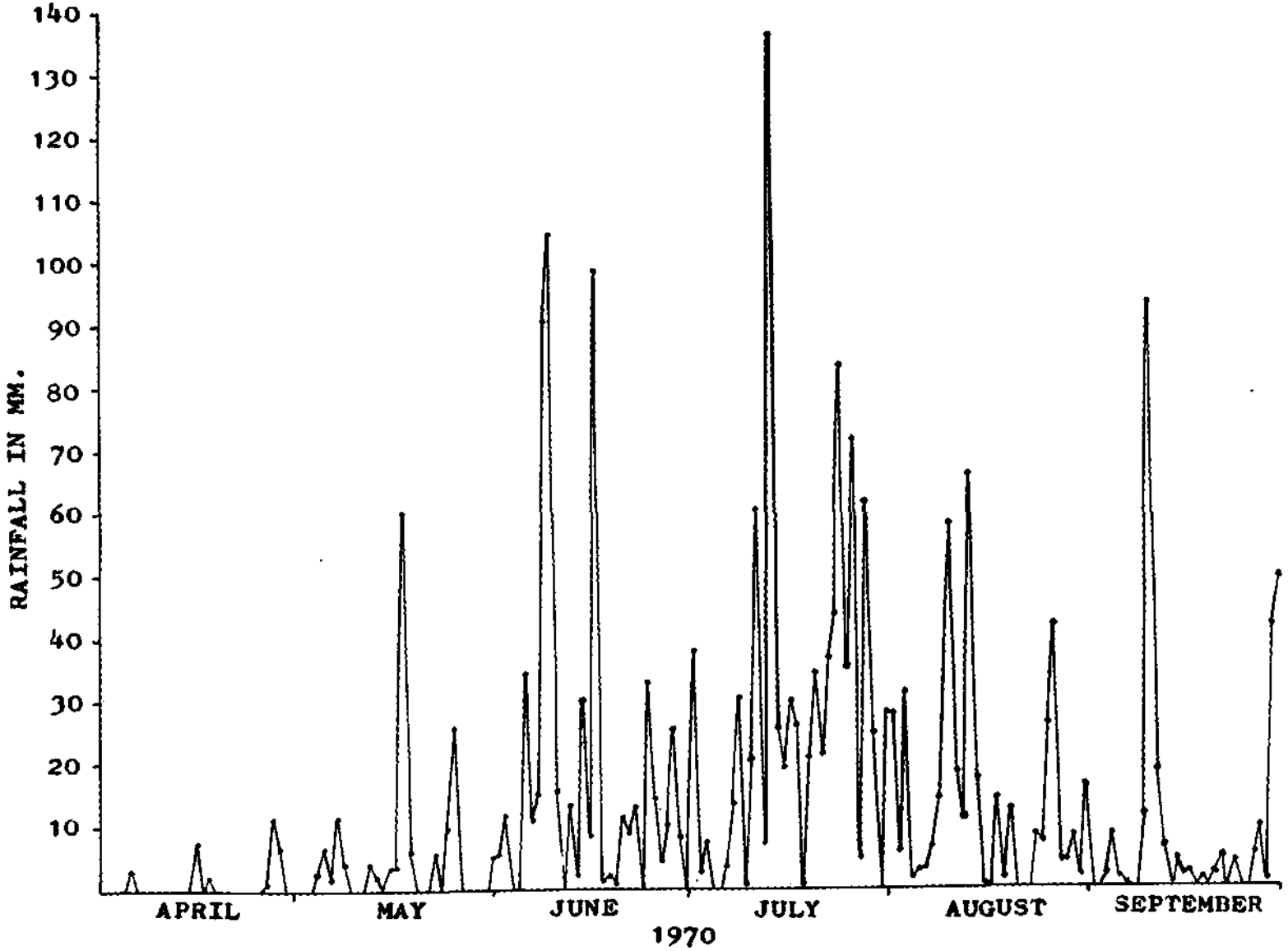

FIG.12: The rainfall in Darjeeling from April 1, 1970 to September 30, 1970

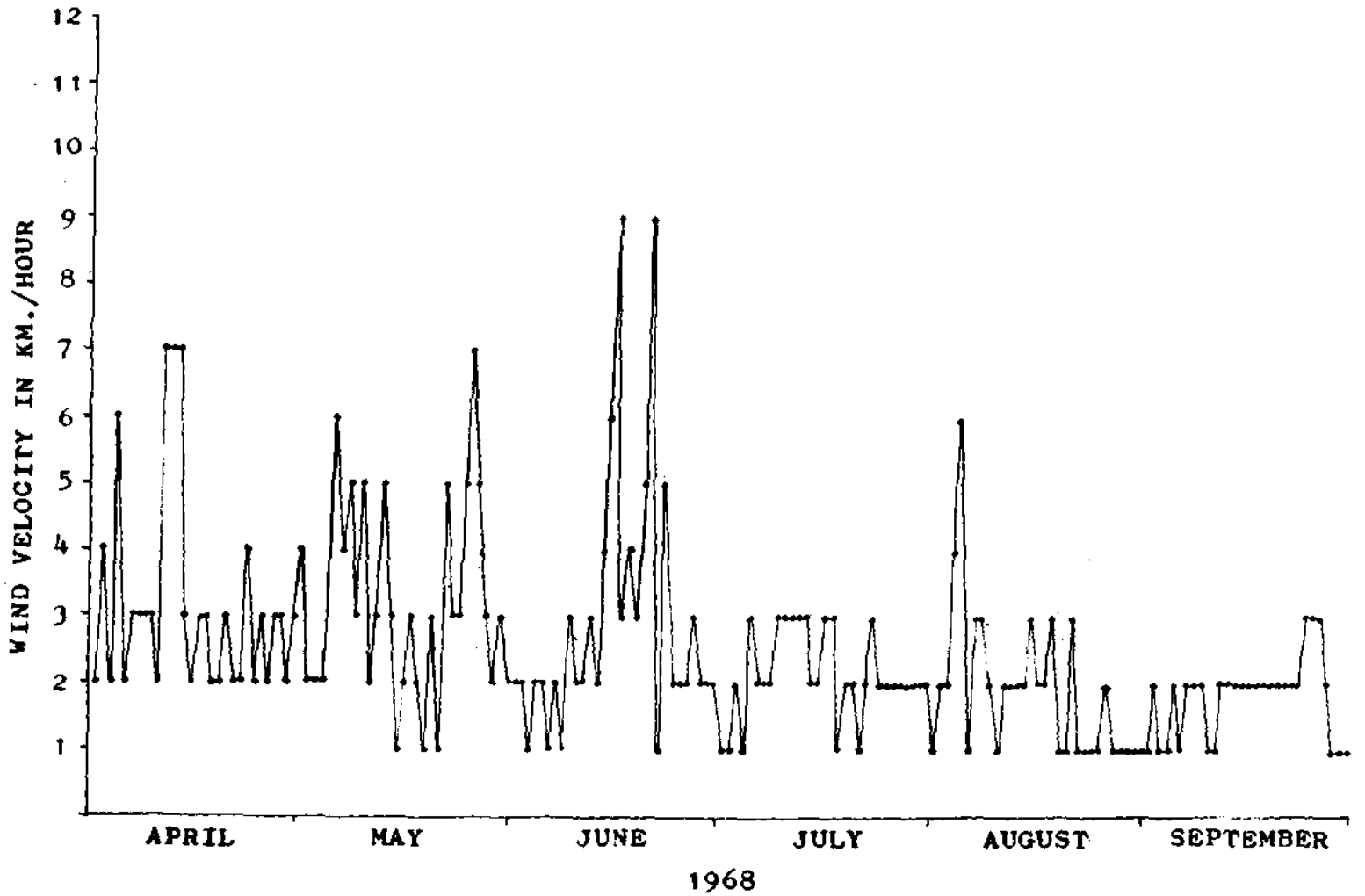

FIG.13: The wind velocity in Darjeeling from April 1 to September 30, 1968

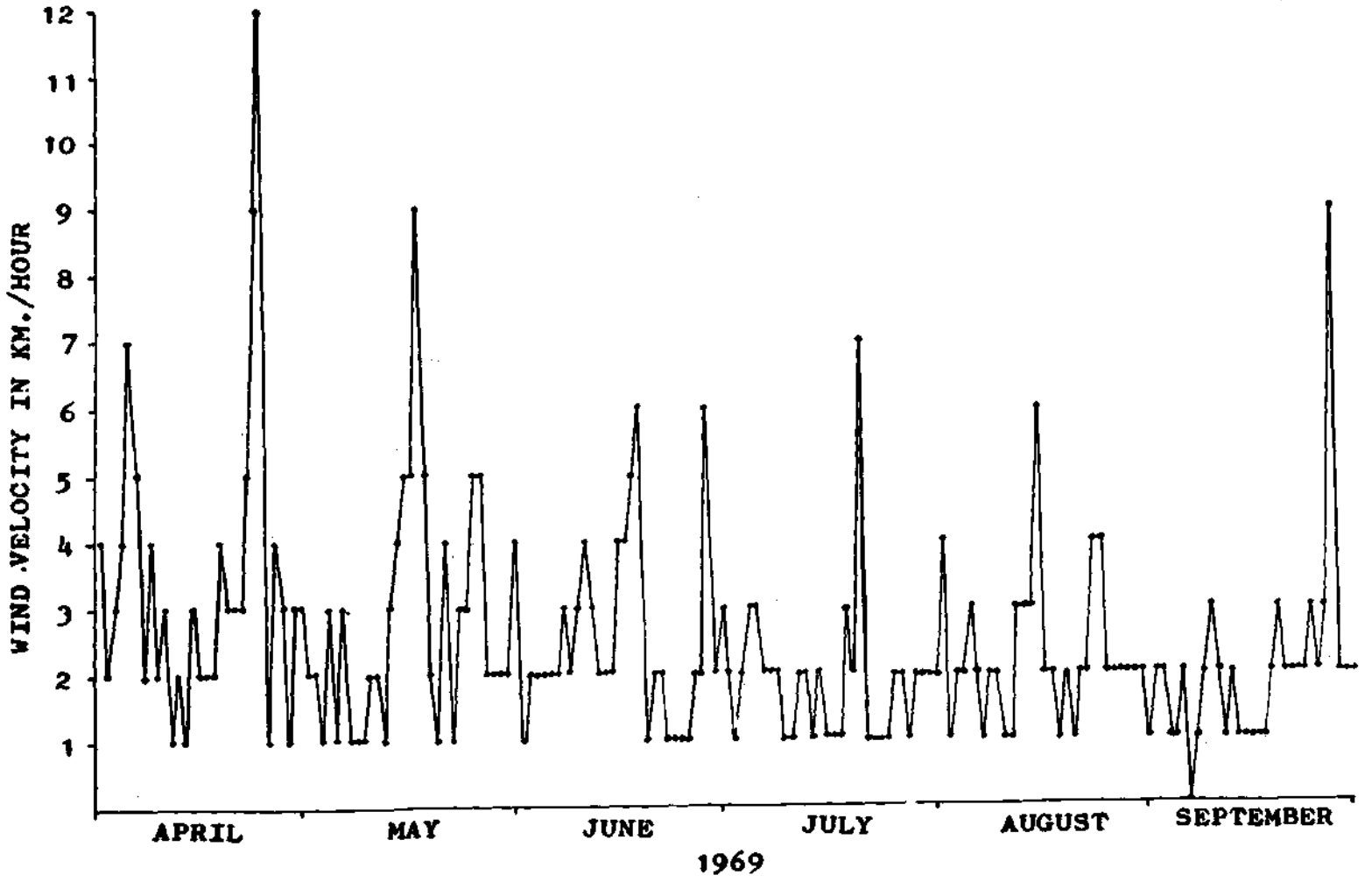

FIG.14: The wind velocity in Darjeeling from April 1 to September 30, 1969

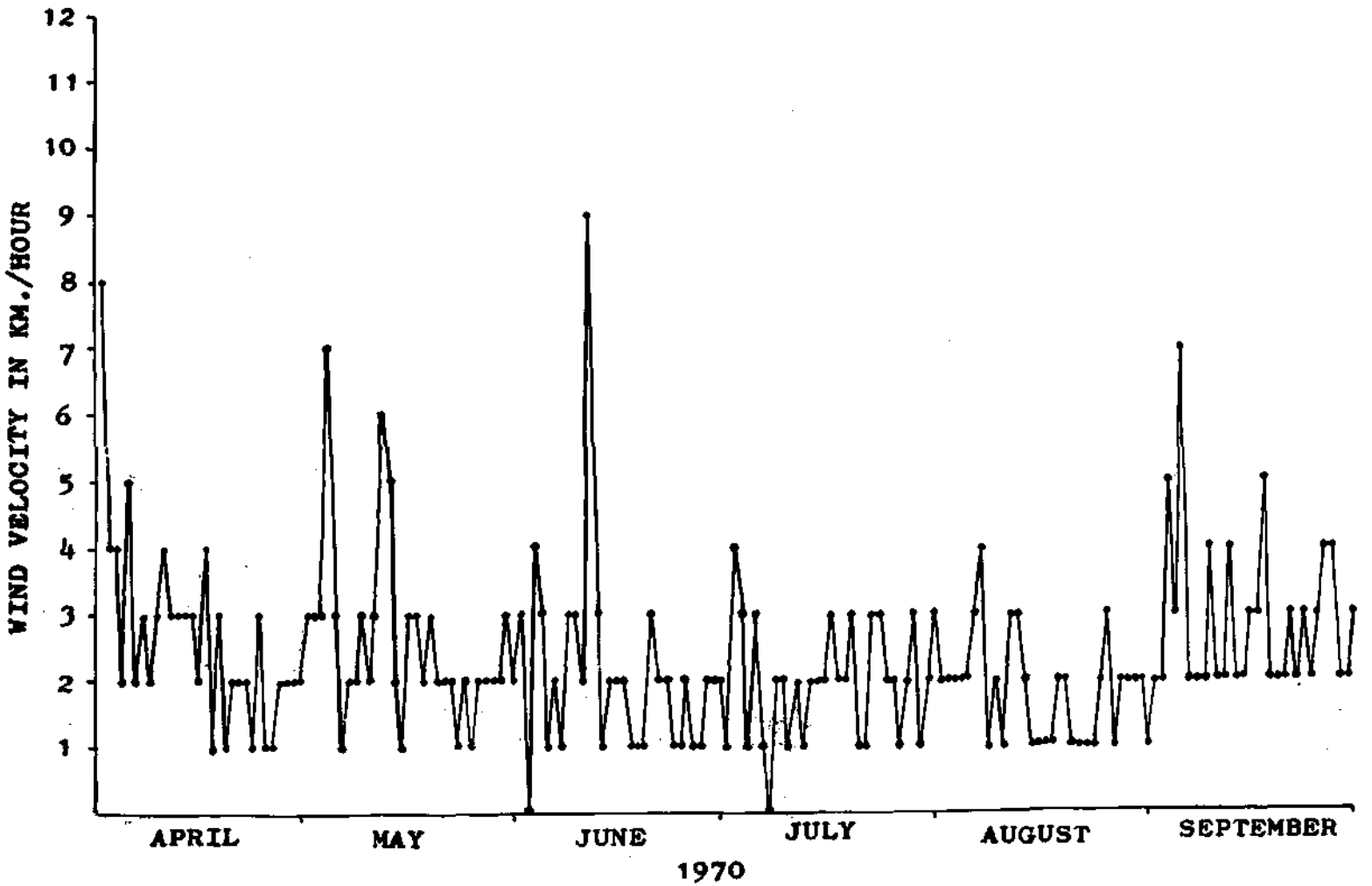

FIG.15: The wind velocity in Darjeeling from April 1 to September 30, 1970

The figures of rain fall (Figs.10-12) and wind velocity (Figs.13-15) are given here, and those of maximum and minimum temperature and mean relative humidity are given with the incidence of black flies in the following pages.

Discussion

The light trap device is expected to show more or less the same population-size picture of a given species in an area as that indicated by observations on the aquatic stages in the field, if conditions are favourable in both the situations. Working in Scotland, Williams (1939, 1961) showed beyond doubt that the light trap was a suitable sampling device for night-flying dipterans including black flies.

In the present work the total number of flies caught in 1968 was 1641; in 1969 the number was 1379; and in 1970 the number was 2828. It will be seen that the total number of black flies caught in 1970 nearly equalled the sum total for 1968 and 1969. This result probably did not only mean that the incidence of these flies in the trap was affected by some meteorological factors influencing the imagines or the spontaneous variation of the population-size of the area year to year, but it had another significance. Floods, logging and forest-fire are frequent near the breeding grounds of black flies, which might directly affect the population of these flies in Darjeeling as were also shown

by Wolfe and Peterson (1959) in Quebec. It is recalled in this context that in the late rainy season of 1968 there was extensive rain-fall and widespread land-slides in the area of investigation. This natural calamity disturbed the habitats of the black flies. The poor catch in 1968 was likely to be due to this natural calamity; and the lowest incidence of 1969 was mainly due to the preparation of suitable beds for the early aquatic stages of black flies, the adults of which flourished in 1970.

It was also found that in 1968, as well as in 1969 the black flies were most abundant in the months of May and June; whereas in 1970 the maximum availability of the insect was in April, though the insects were also abundant in May and June of that year. The above observation perhaps reflected the overlapping in life-cycles of at least some species.

The higher incidence of the insects in September than in August in all these three years was perhaps due to the occurrence of second generation of some species of black flies. It will be recalled in this context that Davies and Williams (1962) were of opinion that the light trap was expected to provide some information regarding successive generations of black flies as indicated by their incidence pattern. In the same way, the sex-ratio of a species, behavioural difference and their periodicity at night might be explained in the light of a trap device, though according to these workers some species of black

flies might not respond to the light trap during darkness in spite of their abundance.

In course of the analysis of trap data recorded in Scotland, Williams (1962) emphasised the importance of both preceding and current weather conditions. In the present investigation the optimum flying activity of black flies was recorded in the temperature between 14°C and 25°C, in the relative humidity of 65%-80%, in little or no rain fall and almost in calm wind. In Central Asia, Rubtzov (1939) noted that the flying activity was normal at temperatures between 10°C and 29°C with the optimum at about 20°C - 23°C and at 75%-90% humidity while in Canada, Davies (1952) observed more flies on the wings at temperatures between 15.5°C and 26.6°C with the optimum range from 24°C to 26.6°C, in moist air, i.e., at 70%-90% relative humidity and at wind velocity below 24 Km./hour. Working in Quebec, Wolfe and Peterson (1960) observed that the flight activity appeared to depend on light intensity if the temperature was not below 7.2°C, the wind velocity not above 3.2 Km./hour and the relative humidity not below 50%. Williams (1962) at the time of his extensive light trapping in Scotland observed the highest activity to occur on nights with high minimum temperature, with falling pressure and with quite heavy rain or no rain at all.

In the light of the present investigation it is clear that the incidence of black flies taken in the light trap was

the consequence of the interplay of a good many factors, viz., ecological factors, meteorological factors and other probable factors of physiological nature.

Summary

The efficacy of the light trap used in capturing black flies is discussed with reference to the incidence of these insects in relation to the environmental conditions. The total number of black flies captured was 1641 in 1968, 1379 in 1969 and 2828 in 1970 with a grand total of 5848 during April to September of each year. In 1968 and 1969 the maximum availability of these flies was registered in May and June, while in 1970 the period of maximum availability was in April in addition to May and June. It is considered that the extensive rain-fall and wide spread land-slides of 1968 had a direct impact on the incidence of the black flies in and around Darjeeling. The optimum flying activity of these flies was recorded in the temperature between 14°C and 25°C, in the mean relative humidity of 65%-80%, in little or no rain fall, and almost in calm wind.

RELATIVE ABUNDANCE

Introduction

The earlier works of Zahar (1951), Williams and Davies (1957), and Davies and Williams (1962) have shown that both field collection and light trapping are essential steps for assessing the relative abundance of various photophilic insects like black flies (Simuliidae:Diptera). According to these workers there is a remarkable variation in the incidence of each species of black flies in every month on the basis of species-population of a particular area. In the present study attempt has been made to determine the relative abundance of different species of black flies from the annual picture of appearance of these insects taken in light trap in Darjeeling.

Method

Black flies were collected by continuous light trapping between 7 P.M. and 5 A.M. at Darjeeling Government College campus in 1790 trap-hours of 179 nights from April 1, 1968 to September 30, 1968; in 1800 trap-hours of 180 nights from April 1, 1969 to

September 30, 1969; and in 1810 trap-hours of 181 nights from April 1, 1970 to September 30, 1970, with the help of a simple light trap device described in page no.132.

Result

Black flies collected by the above method were found to consist of six major species, namely Simulium (Eusimulium) praelargum n.sp., S.(E.) gracilis n.sp., Simulium (Simulium) himalayense Puri (1932a), S.(S.) grisescens Brunetti (1911), S.(S.) rufibasis Brunetti (1911) and Simulium (Gomphostilbia) tenuistylum n.sp., and also a few other minor species.

The total numbers of black flies captured in each of the three years were 1641 in 1968, 1379 in 1969 and 2828 in 1970 with a grand total of 5848 during the whole study period. The total numbers of each of the six major species of black flies in each of three years, their percentage occurrence and their average are shown in Table IX.

Table-IX

Total numbers of specimens of six species of black flies, their percentage occurrence for 1968, 1969 and 1970 and their average

Species	Total no. of specimens				% occurrence			
	1968	1969	1970	Average	1968	1969	1970	Average
praelargum	264	283	581	376.0	16.08	20.52	20.55	19.29
gracilis	131	192	365	229.3	7.98	13.92	12.91	11.76
himalayense	460	353	921	578.0	28.05	25.60	32.58	29.66
grisescens	302	183	277	254.0	18.40	13.27	9.79	13.03
rufibasis	276	195	422	297.7	16.82	14.15	14.92	15.27
tenuistylum	208	173	262	214.3	12.67	12.54	9.25	10.99

Thus, according to their decreasing abundance these six species of black flies may be arranged in the following three groups for each of the three years (Tables X - XIII)

Table-X

Relative abundance of six species of black flies in 1968

Group A:	Dominant (over 25%)	
	himalayense	28.05%
Group B:	Abundant (between 15% and 25%)	
	grisescens	18.4%
	rufibasis	16.82%
	praelargum	16.08%
Group C:	Sparse (between 15% and 5%)	
	tenuistylum	12.67%
	gracilis	7.98%

Table-XI

Relative abundance of six species of black flies in 1969

Group A:	Dominant (over 25%)	
	himalayense	25.6%
Group B:	Abundant (between 15% and 25%)	
	praelargum	20.52%
Group C:	Sparse (between 5% and 15%)	
	rufibasis	14.15%
	gracilis	13.92%
	grisescens	13.27%
	tenuistylum	12.54%

Table-XII

Relative abundance of six species of black flies in 1970

Group A:	Dominant (over 25%)	
	himalayense	32.58%
Group B:	Abundant (between 15% and 25%)	
	praelargum	20.55%
Group C:	Sparse (between 5% and 15%)	
	rufibasis	14.92%
	gracilis	12.91%
	grisescens	9.79%
	tenuistylum	9.25%

Table-XIII

Relative abundance of six species of black flies in average (1968, 1969 and 1970)

Group A:	Dominant (over 25%)	
	himalayense	29.66%
Group B:	Abundant (between 15% and 25%)	
	praelargum	19.29%
	rufibasis	15.27%
Group C:	Sparse (between 5% and 15%)	
	grisescens	13.03%
	gracilis	11.76%
	tenuistylum	10.99%

In addition to these six species of black flies mentioned in the above tables there were a few minor species including S.(E.) purii n.sp., S.(E.) nemorivagum n.sp., S.(S.) nigrifacies n.sp., S.(S.) dentatum Puri (1932b), S.(G.) darjeelingense n.sp. and a few other unnamed species. These were rarely found in their natural habitats and they hardly visited the light trap device. These species might be placed in the additional 'rare' group since their populations appeared to be less than 5% in and around the township of Darjeeling.

Discussion

The percentage occurrence of a given species for the three consecutive years showed on remarkable variation, and himalayense

was the only dominant species in the area while praelargum was the abundant species. In average, rufibasis could also be placed in the abundant group, though both in 1969 and 1970 this species found no place in that group. All the other three species, namely, grisescens, gracilis and tenuistylum were found to be sparsely distributed in Darjeeling. It is interesting to note that grisescens scored the highest percentage of incidence in 1968 among the species of the abundant group. This was possibly due to the natural calamity in the middle of the study period of 1968 when there was heavy rain fall and extensive land-slides which apparently disturbed the breeding centres of other species of the group more than the breeding centres of this species.

The incidence of the species of the 'rare' group in the light trap was very poor since their populations were meagre. According to Davies and Williams (1962) certain species of black flies like Prosimulium hirtipes Fries were inactive in the darkness. If certain species of black flies in Darjeeling also are inactive at night, their appearance in the light trap could only be a matter of chance.

Summary

The relative abundance of six species of black flies, namely, S.(E.) praelargum n.sp., S.(E.) gracilis n.sp., S.(S.) himalayense Puri, S.(S.) grisescens Brunetti, S.(S.) rufibasis

Brunetti and S.(G.) tenuistylum n.sp. was studied with the help of light trap data for the three consecutive years, i.e., 1968, 1969 and 1970. These six species were arranged in sequence with himalayense as the dominant species, praelargum and rufibasis as the abundant species, and grisescens, gracilis and tenuistylum as the sparsely distributed species of the area. In addition, comments are made on some species of the 'rare' group of the area of investigation from their low incidence in the trap.

SEASONAL INCIDENCE AND SUCCESSION

Introduction

A striking feature in the bionomics of black flies belonging to the family Simuliidae is that there is a remarkable variation of incidence among the species in every month as revealed by field studies undertaken by earlier workers (see Smart, 1936; Rubtzov, 1939; Stukolkina, 1939; Davies, D.M., 1950; Davies, L., 1951; Peterson and Wolfe, 1956; Davies and Syme, 1958; Wolfe and Peterson, 1959; and Ussova, 1961). Davies and Williams (1962) working with the Rothamsted light trap also came across this type of variation. There is no report on the seasonal distribution and succession of the species of black flies in India. In the present chapter effort has been made to study the incidence of black flies in Darjeeling by continuous light trapping.

Method

Black flies were collected by continuous light trapping between 7 P.M. and 5 A.M. at Darjeeling Government College campus in 1790 trap-hours of 179 nights from April 1, 1968 to September 30, 1968; in 1800 trap-hours of 180 nights from April 1, 1969 to September 30, 1969; and in 1810 trap-hours of 181 nights from

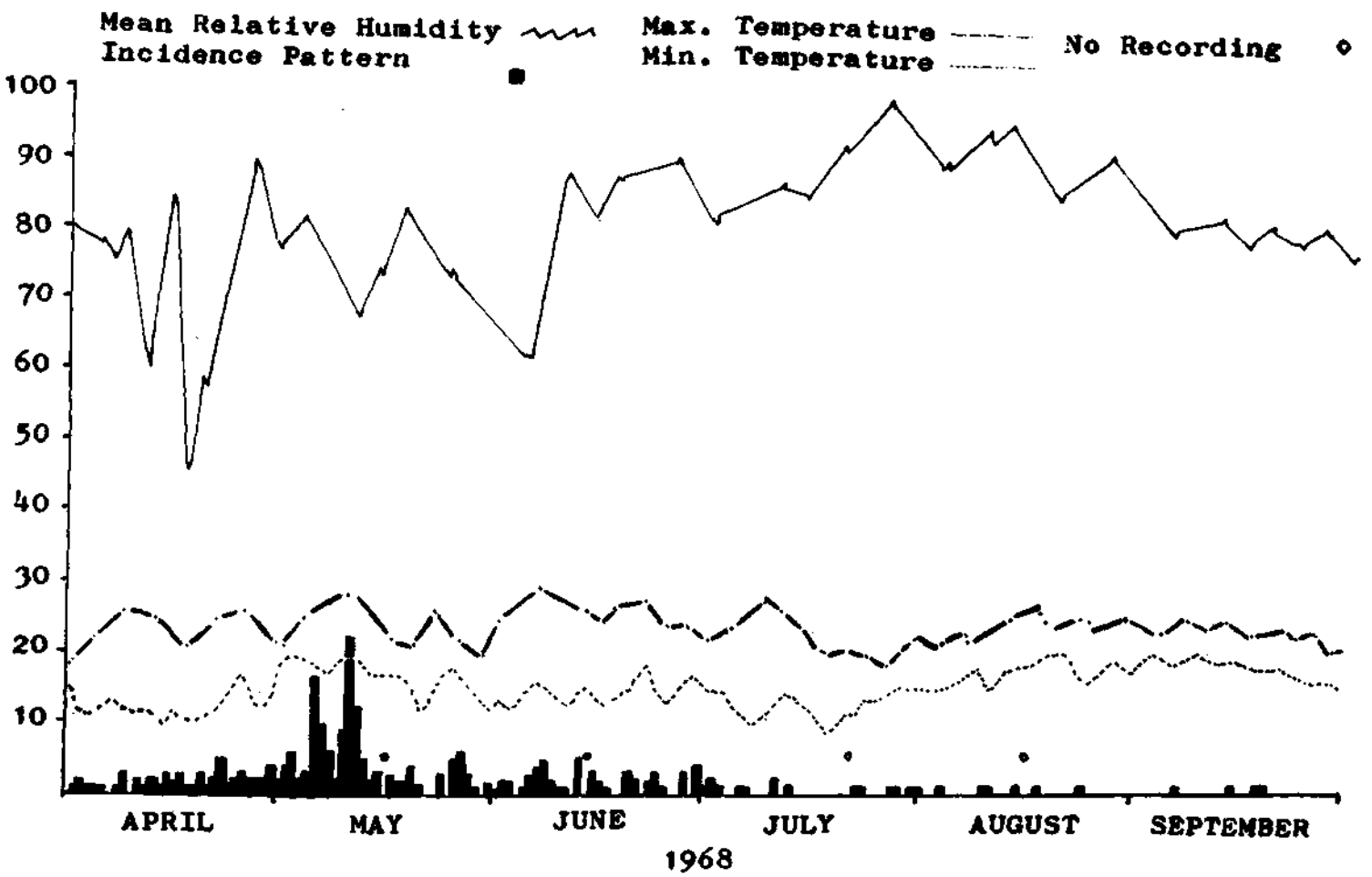

FIG.16: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Eusimulium) praelargum, n.sp. on the abscissa at Darjeeling Government College collecting station from April - September 1968. Figures an the ordinate indicate the quantity

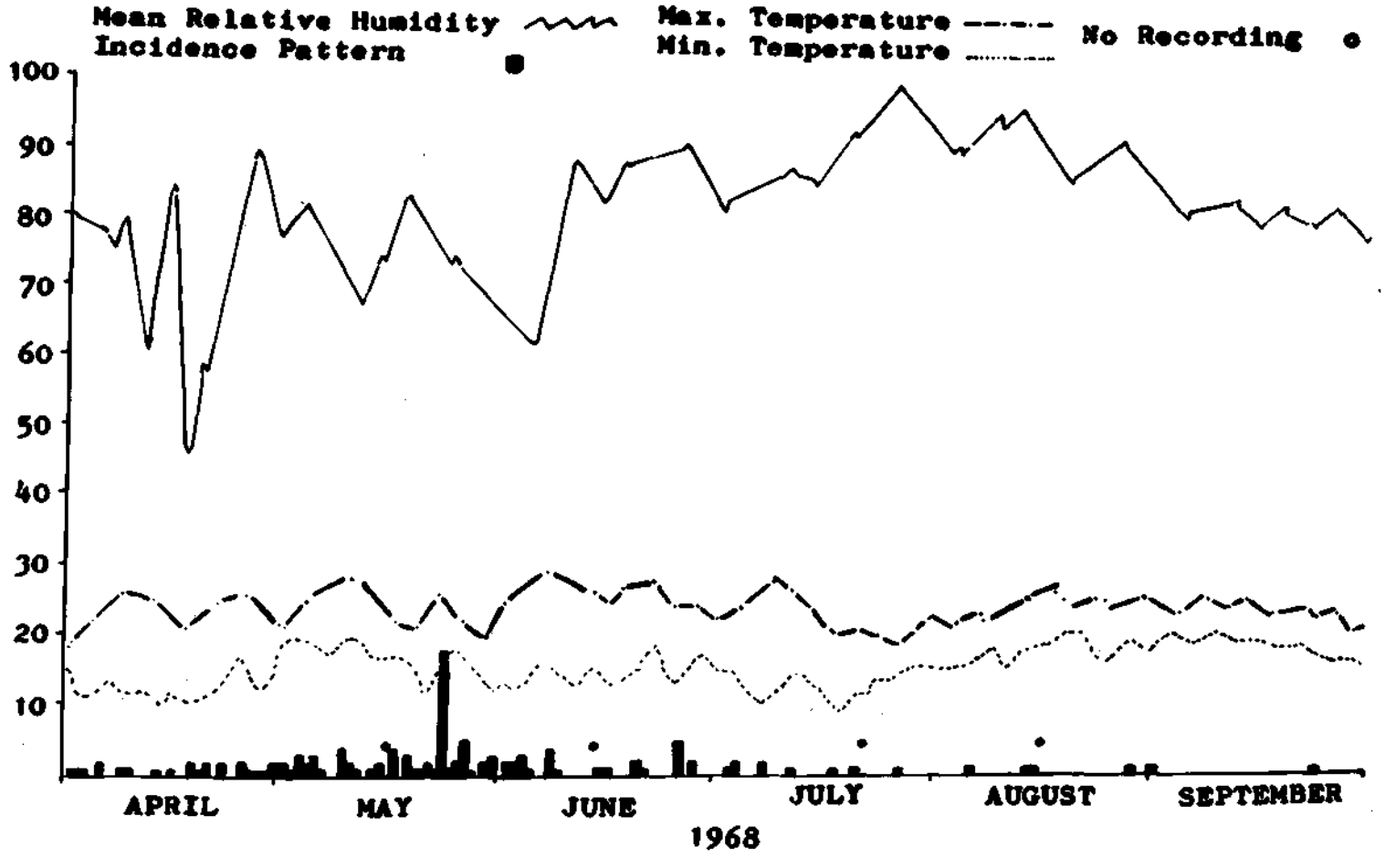

FIG.17: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Eusimulium) gracilis, n.sp. on the abscissa at Darjeeling Government College collecting station from April - September 1968. Figures on the ordinate indicate the quantity

April 1, 1970 to September 30, 1970. The simple light trap device described in page no.132 was used for the purpose.

Observations

Black flies collected by the above method were found to consist of six major species, namely Simulium (Eusimulium) praelargum n.sp., S.(E.) gracilis n.sp., Simulium (Simulium) himalayense Puri (1932a), S.(S.) grisescens Brunetti (1911), S.(S.) rufibasis Brunetti (1911) and Simulium (Gomphostilbia) tenuistylum n.sp., and a few rare species, namely, S.(E.) purii n.sp., S.(E.) nemorivagum n.sp., S.(G.) darjeelingense n.sp., S.(S.) nigrifacies n.sp., S.(S.) dentatum Puri (1932b) and a few other unnamed species. The present study concerns six major species only.

(a) Seasonal incidence in 1968

The peak of praelargum (22 specimens in a single night) was encountered on 11.5.68, the month of May being the period of its maximum availability. There was a rise in incidence with 16 specimens on 6.5.68 before the principal peak. After this peak the population gradually went down. The average nightly turn-up of the species in May was 4.5 specimens and that of the species in the whole period was 1.47 specimens.

The peak abundance of gracilis was observed in the last part of May, 18 specimens being trapped on 24.5.68 and this was

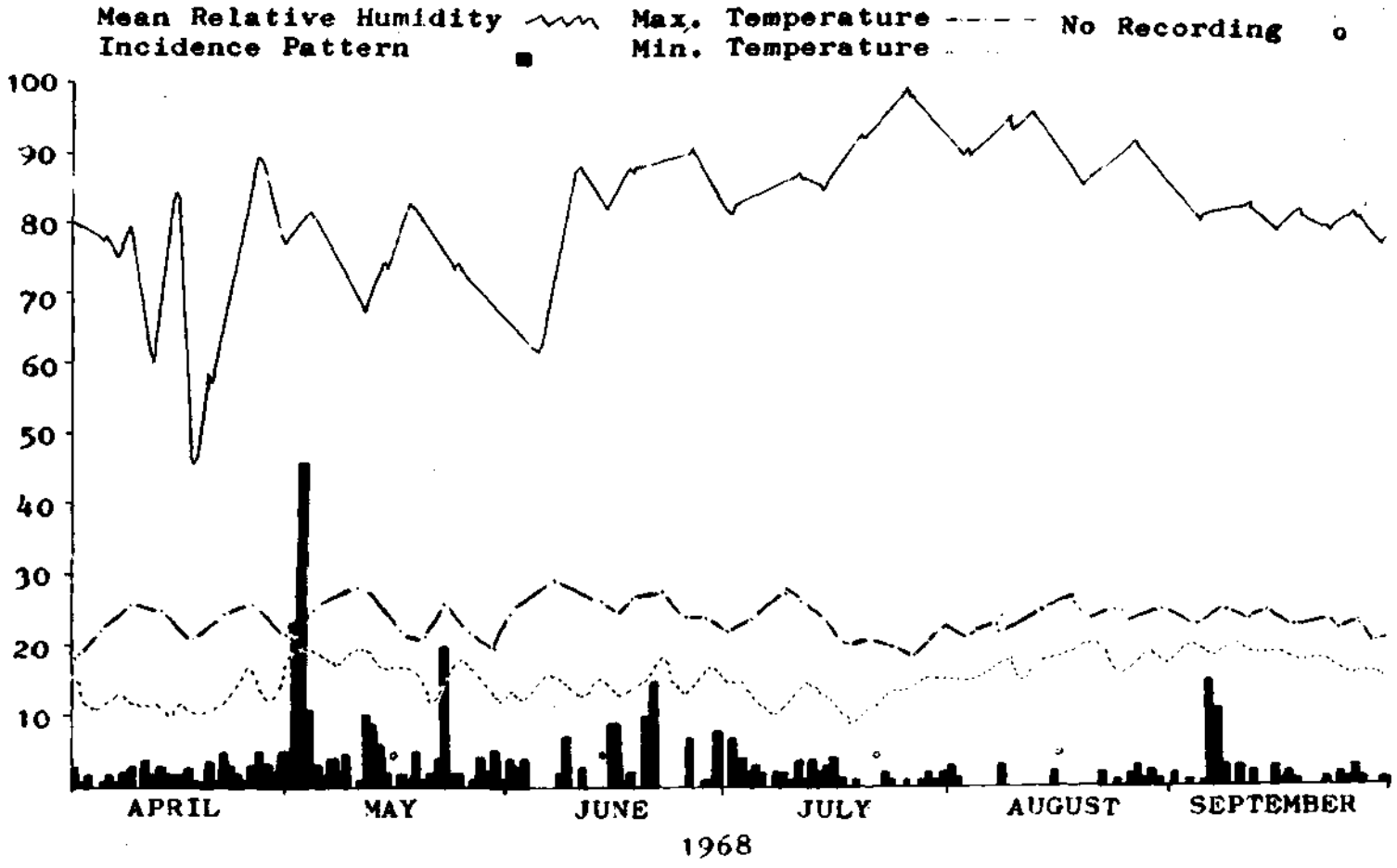

FIG.18: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Simulium) himalayense Puri (1932) on the abscissa, at Darjeeling Government College collecting Station from April - September, 1968. Figures on the ordinate indicate quantity

April and May but this species attained its peak almost suddenly

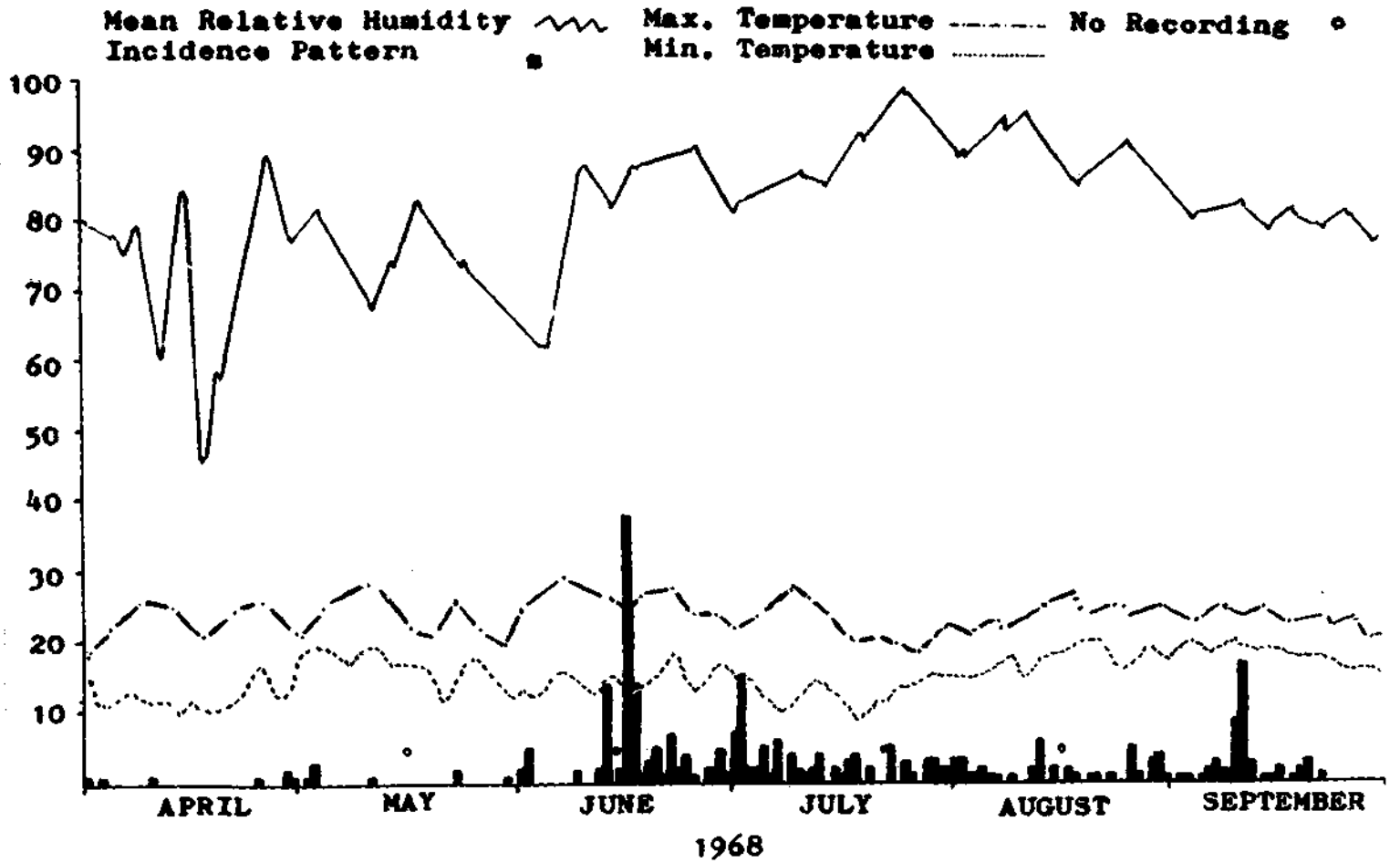

FIG.19: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Simulium) grisescens Brunetti (1911) on the abscissa, at Darjeeling Government College collecting Station from April - September, 1968. Figures on the ordinate indicate quantity

the maximum record for any single night. On the whole, the population showed an abrupt rise and also an abrupt decline. In September, only 2 specimens were recorded for the whole month. The hightly average catch in May was 2.26 specimens and that in the whole period only 0.73 specimens.

The peak abundance of himalayense was observed on 3.5.68. with trapping of 46 specimens, and the population tended to decline gradually with a number of rise and fall upto July. In August the incidence was significantly poor but in September the population represented a small sub-ordinate peak with 15 specimens on 6.9.68. The average nightly turn up of the species in May was 5.93 specimens; that in June 2.87 specimens; that in September 1.8 specimens; and that in the whole period 2.57 specimens.

S.(S.) grisescens was practically unrepresented both in April and May but this species attained its peak almost suddenly with 38 specimens on 16.6.68. The decline was very gradual with rise and fall in the following months upto August and in September there was a sub-ordinate peak with 17 specimens recorded on 11.9.68. The nightly average catch of the species was 3.9 specimens in June; 2.63 specimens in July; 1.43 specimens in August; 1.73 specimens in September; and 1.68 specimens in the whole period.

The peak abundance of rufibasis was observed in the middle of June, 48 specimens being trapped on 13.6.68., and this

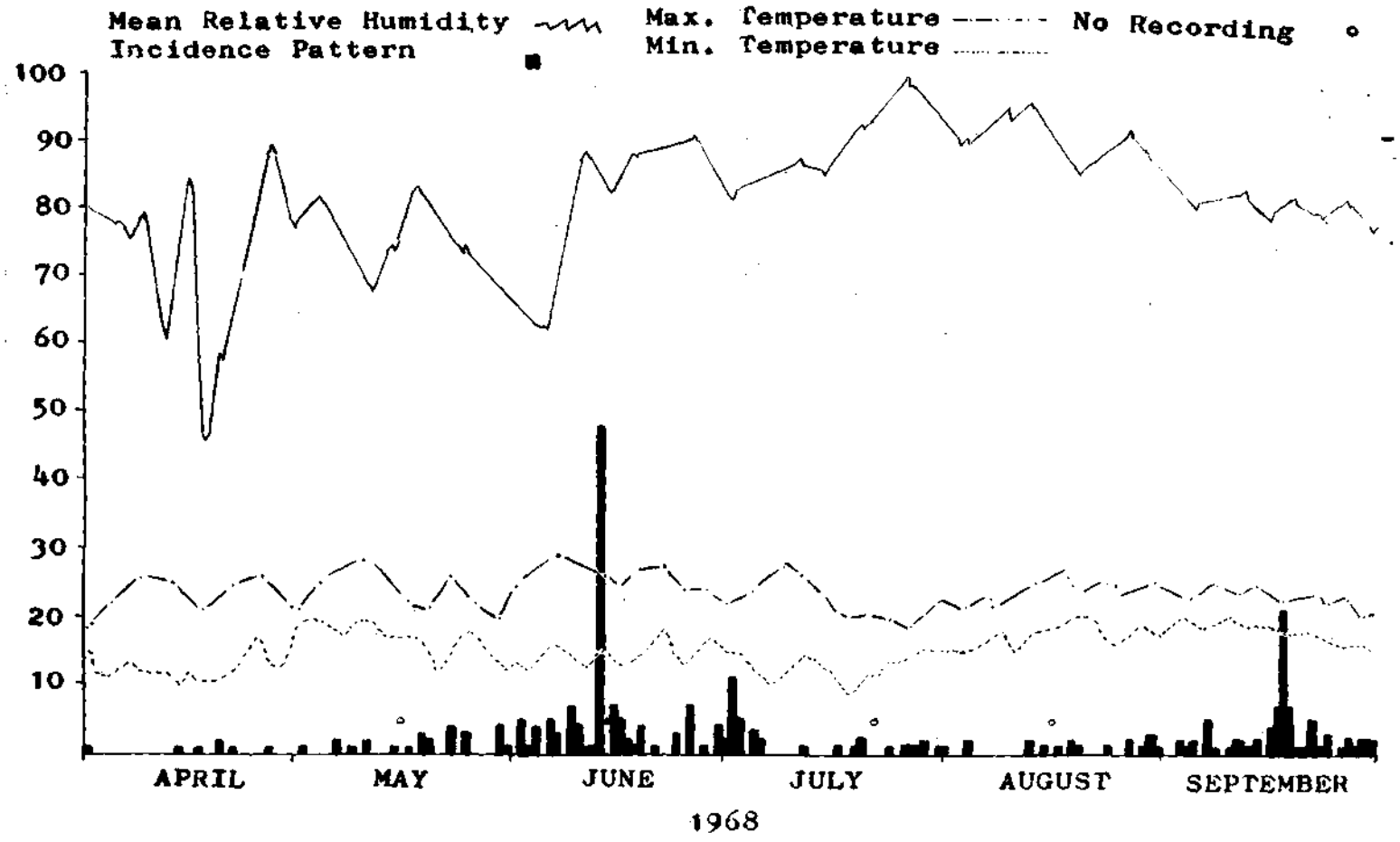

FIG.20: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Simulium) rufibasis Brunetti (1911) on the abscissa, at Darjeeling Government College collecting Station from April - September,1968. Figures on the ordinate indicate quantity

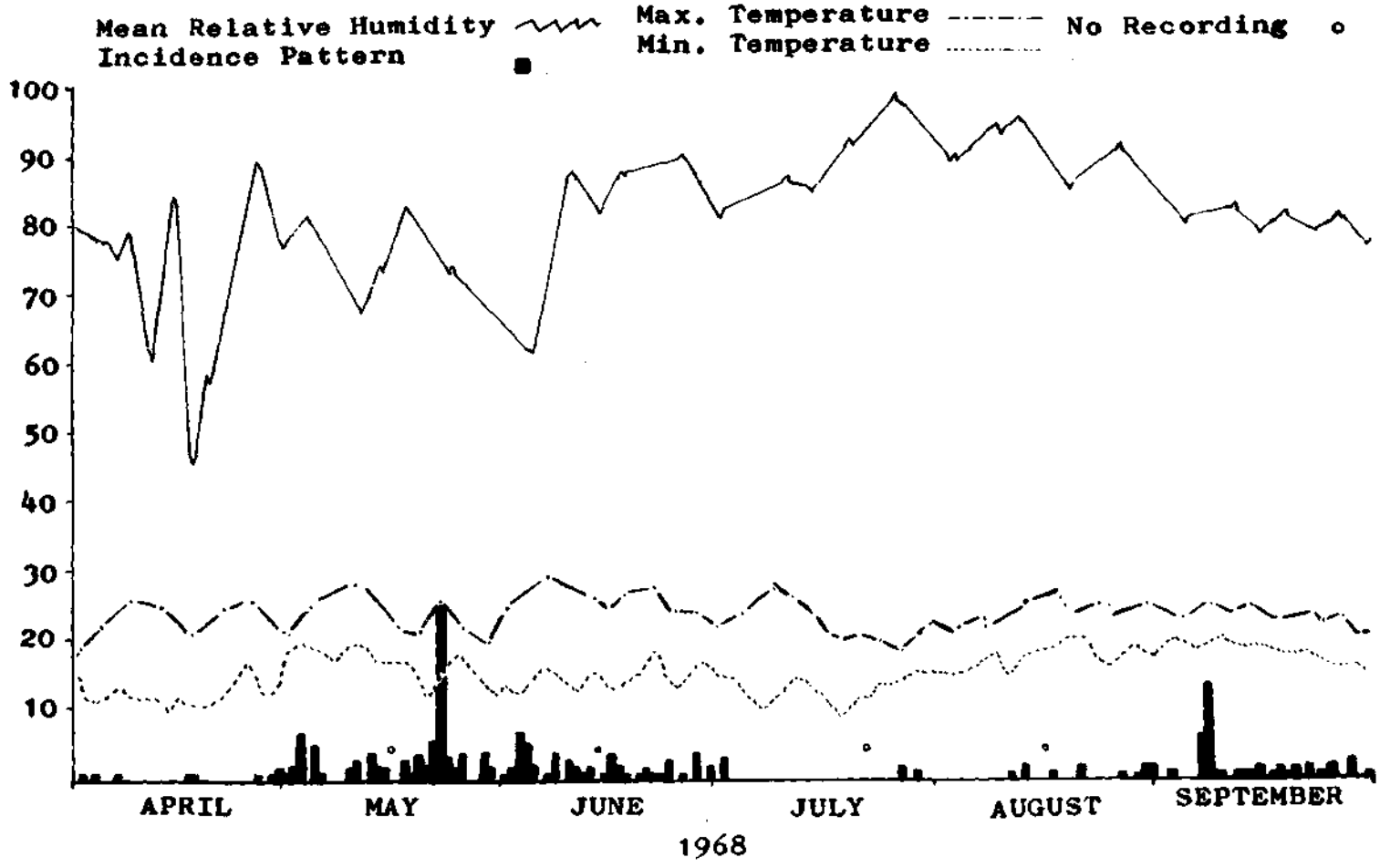

FIG.21: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Gomphostilbia) tenuistylum, n.sp. on the abscissa at Darjeeling Government College collecting Station from April - September, 1968. Figures on the ordinate indicate quantity

was the maximum for any single night. The rise and fall to and from the peak was very abrupt. The population showed a sub-ordinate peak in September, with 21 specimens on 18.9.68. Here also the rise and fall to and from the peak was very abrupt. The average nightly turn-up of the species was 3.9 in June; 2.65 in September; and 1.54 specimens in the whole period.

The peak abundance of tenuistylum was shown in the last part of May, with 25 specimens recorded on 23.5.68. The population began to wane steadily upto the end of June and increased to a certain extent in September with a sub-ordinate peak with 14 specimens on 8.9.68. This species was practically unrepresented in April, July and August with only 9, 6 and 12 specimens respectively. The average nightly turn-up of the species was 2.87 specimens in May; that in June 1.83 specimens; that in September 1.43 specimens and that in the whole period 1.16 specimens.

The above incidence patterns of the six species of black flies of the study area and within the study period are shown along with the patterns of the existing relative humidity and atmospheric temperature in Figs.16-21.

(b) Seasonal incidence in 1969

S.(E.) praelargum attained its peak in the middle of May with 28 specimens trapped on 14.5.69., this being the maximum for any single night. The rise in the incidence was very steady

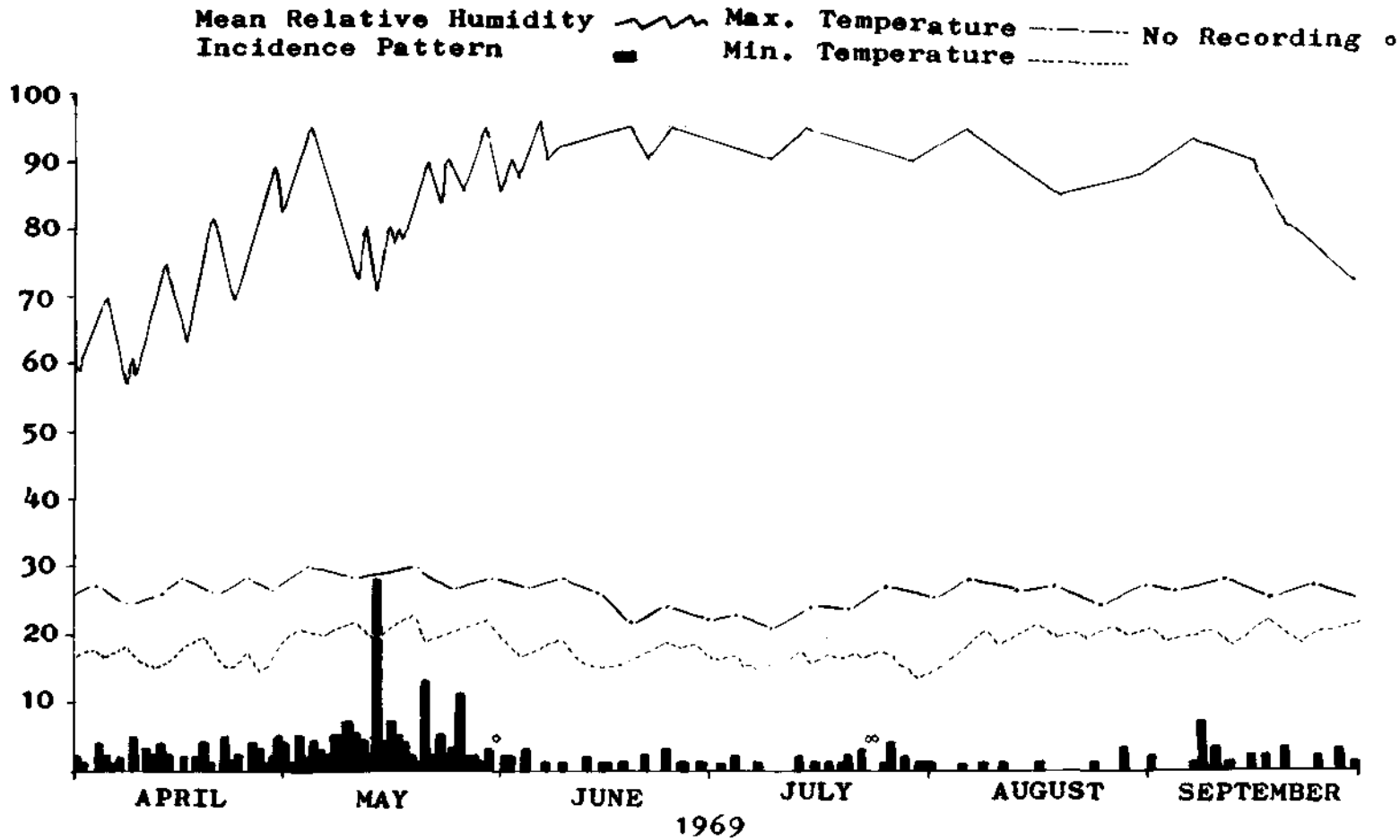

FIG.22: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Eusimulium) praelargum, n.sp. on the abscissa, at Darjeeling Government College collecting station from April - September 1969. Figures on the ordinate indicate the quantity

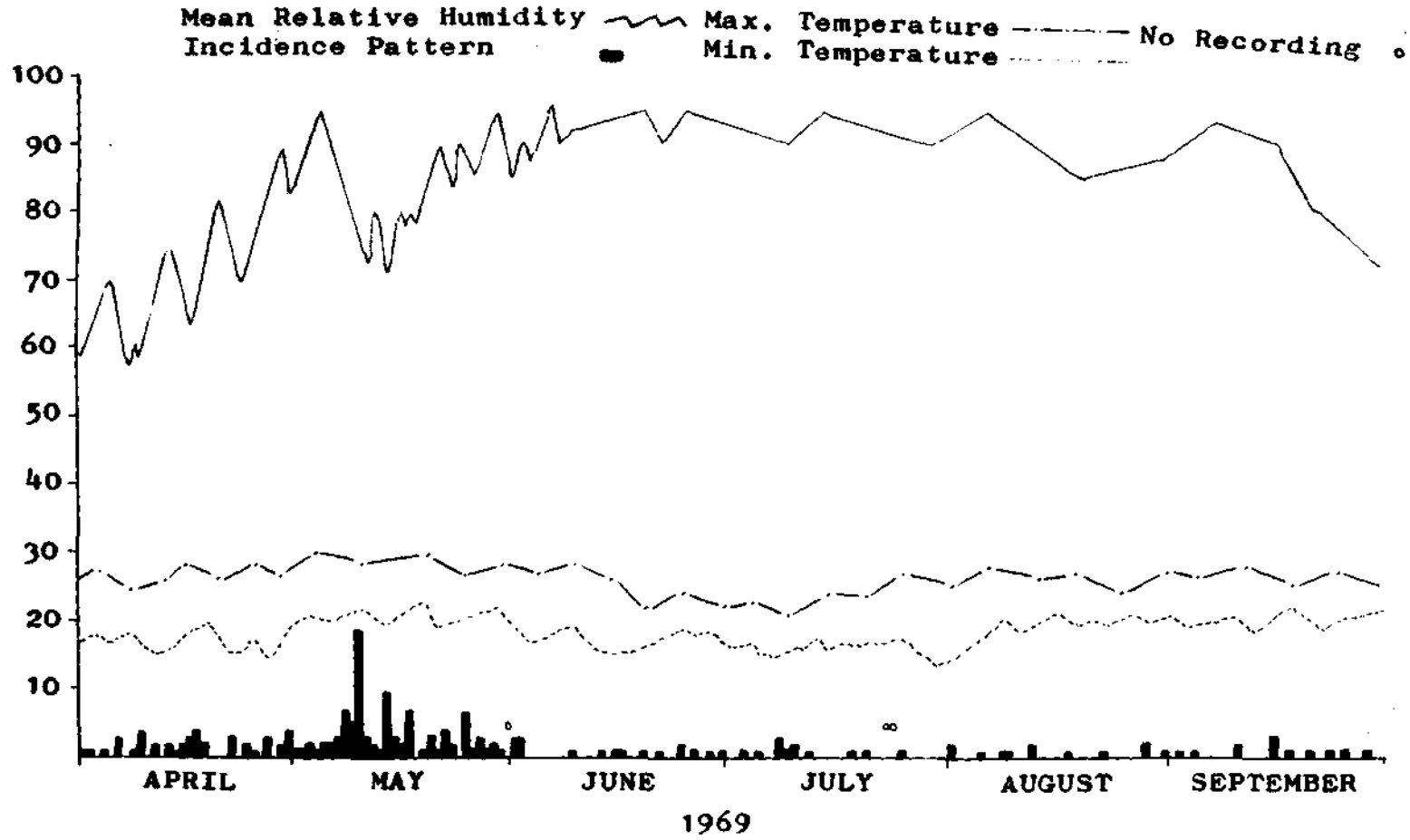

FIG.23: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Eusimulium) gracilis, n.sp. on the abscissa, at Darjeeling Government College collecting station from April - September 1969. Figures on the ordinate indicate the quantity

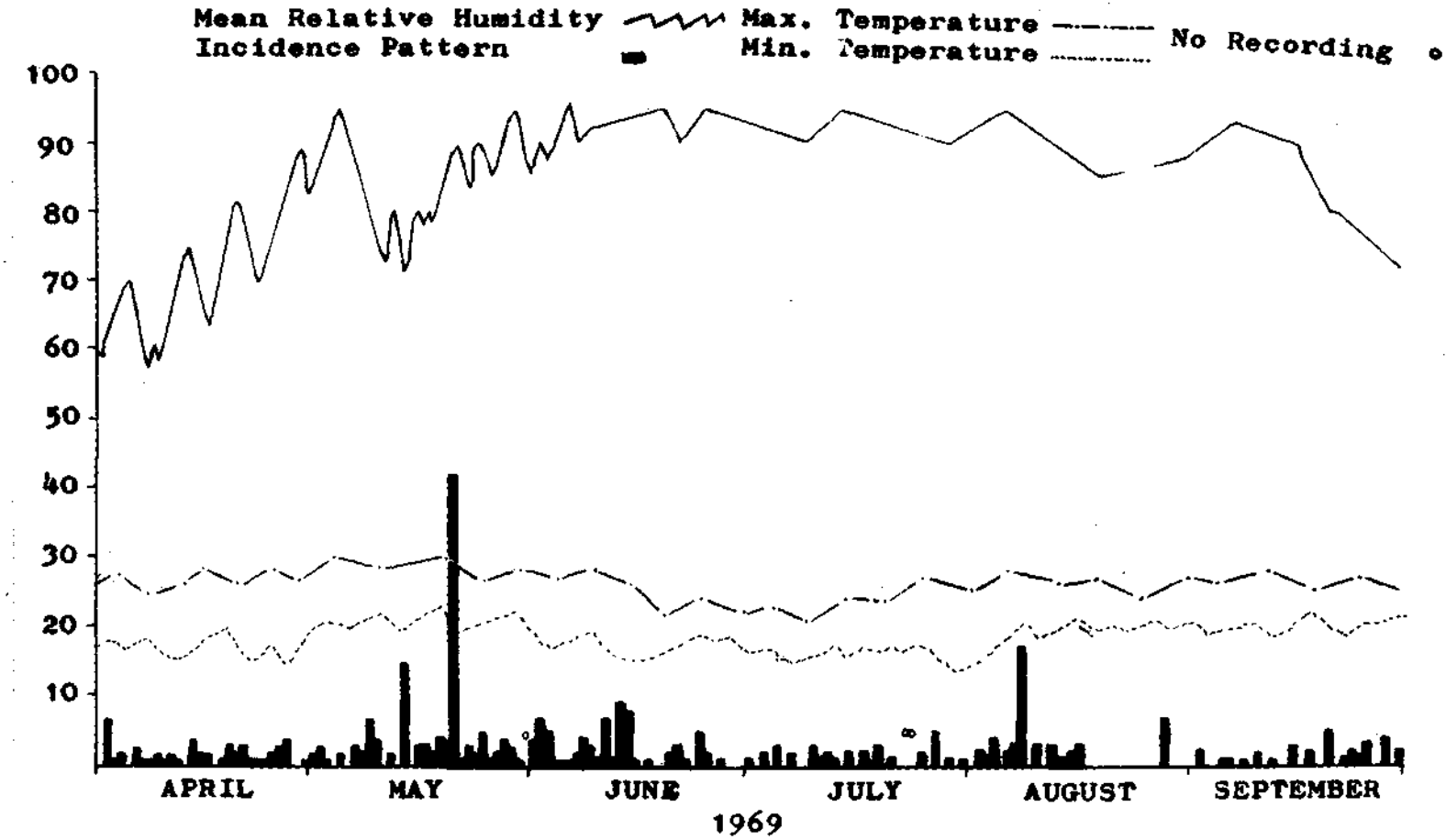

FIG.24: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Simulium) himalayense Puri (1932) on the abscissa, at Darjeeling Government College collecting Station from April - September, 1969. Figures on the ordinate indicate quantity

from the first part of April, and after the principal peak the population began to decline almost abruptly with a little rise and fall. In August the incidence was very poor, and in September a little rise was noticed. The average nightly turn-up of the species was 2 specimens in April; 4.73 in May; 0.9 in September; and 1.57 specimens in the whole period.

The peak abundance of gracilis was observed on 10.5.69 with trapping of 19 specimens. The peak was attained almost suddenly, and after that the trend fell down with the end of May. The incidence of the following months was very poor. The nightly average catch in April was 1.4 specimens, in May 3.23 specimens and in the whole period 1.07 specimens.

The peak abundance of himalayense was observed in the last part of May, with 42 specimens on 21.5.69. The trend was shown from April and the incidence following the month of its peak abundance was maintained almost constantly. In August, a subordinate peak was experienced on 8.8.69, with 17 specimens. The nightly average turn-up was 1.7 specimens in April; 4 in May; 2.33 in June; 1.11 in July; 1.6 in August; 1.03 in September; and 1.97 in the whole period.

S.(S.) grisescens was practically unrepresented in April with only 3 specimens for the whole month. The species attained its peak with 31 specimens recorded on 26.5.69., this being the maximum for any single night. The peak was attained almost

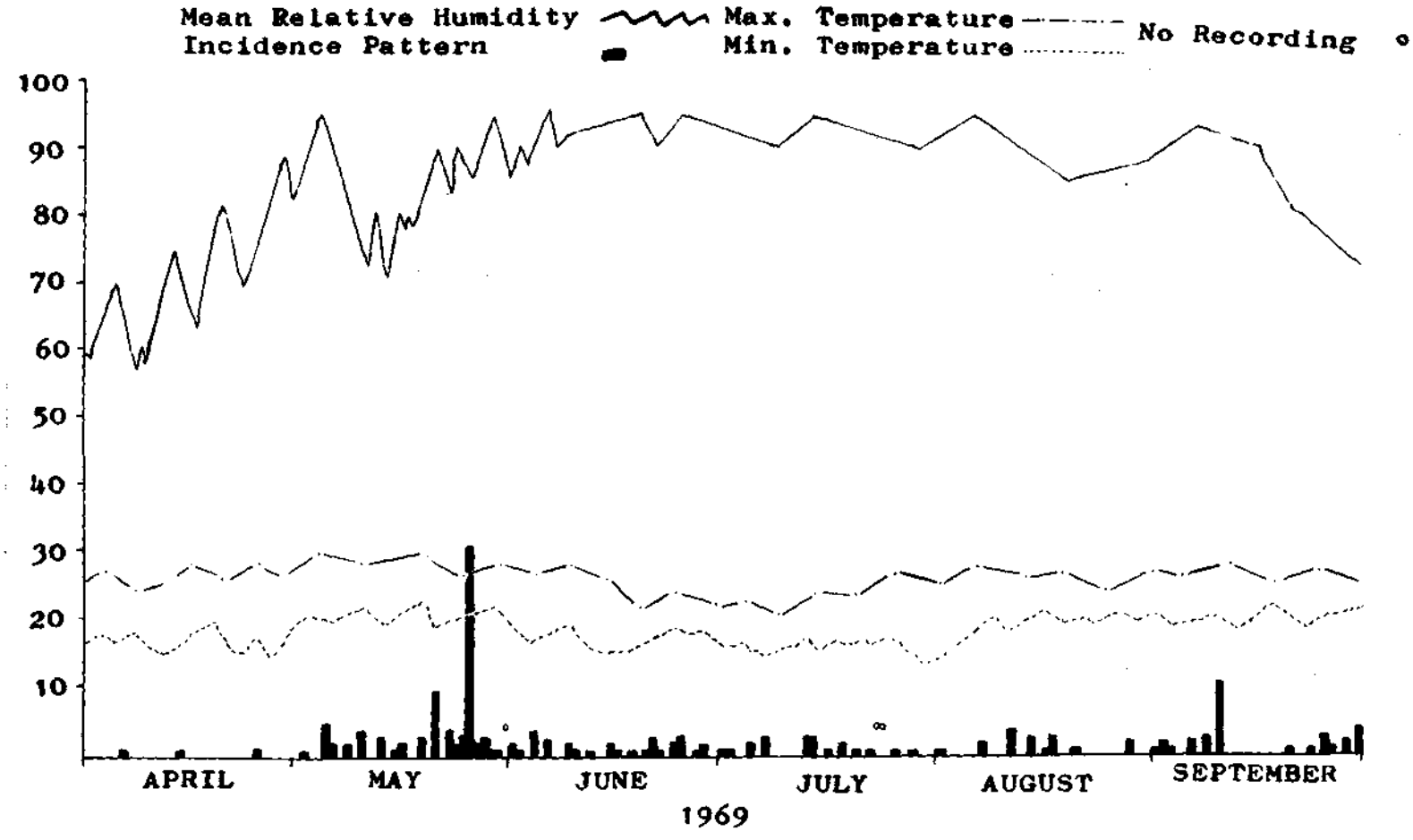

FIG.25: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Simulium) grisescens Brunetti (1911) on the abscissa, at Darjeeling Government College collecting Station from April - September, 1969. Figures on the ordinate indicate quantity

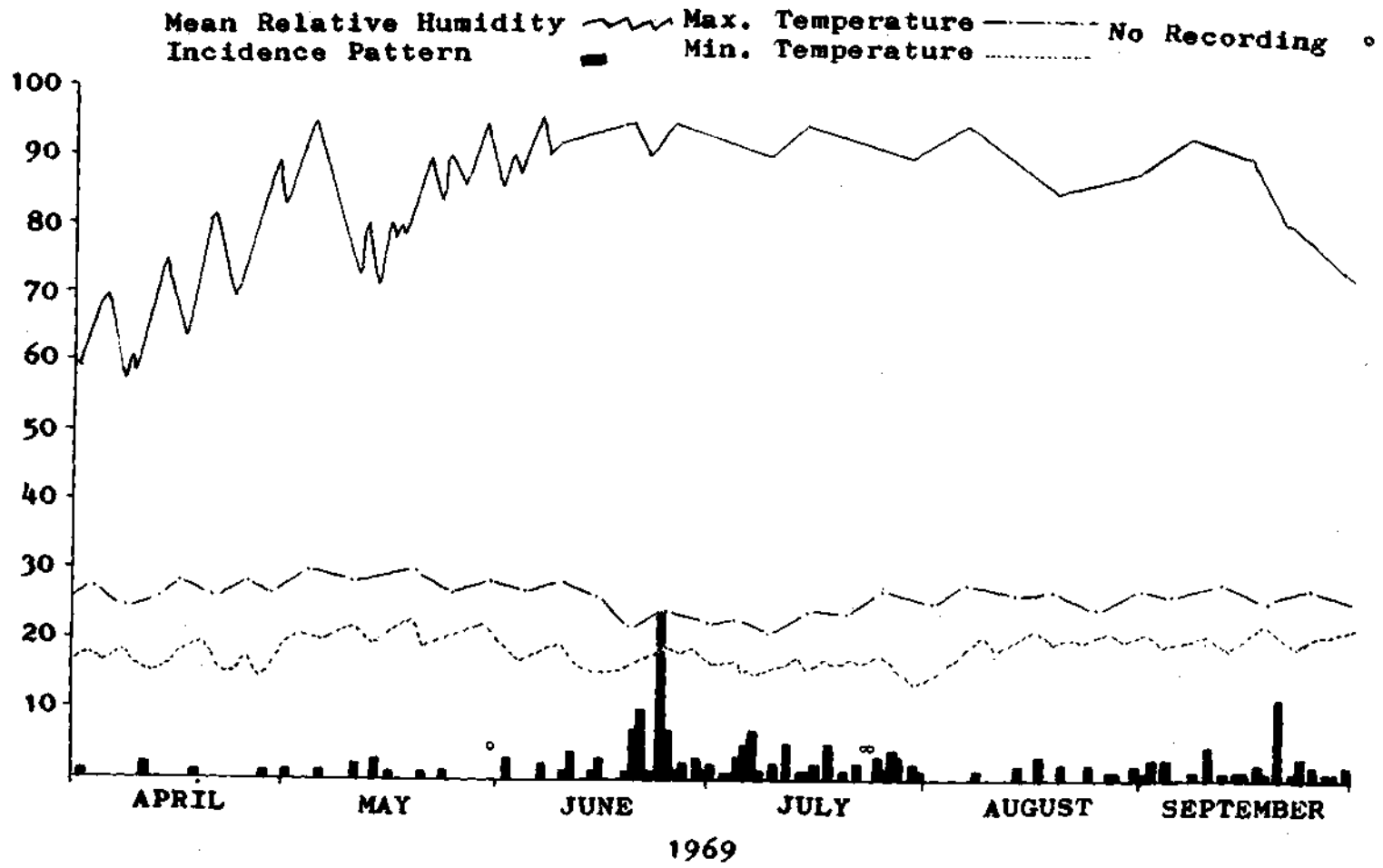

FIG.26: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Simulium) rufibasis Brunetti (1911) on the abscissa, at Darjeeling Government College collecting Station from April - September, 1969. Figures on the ordinate indicate quantity

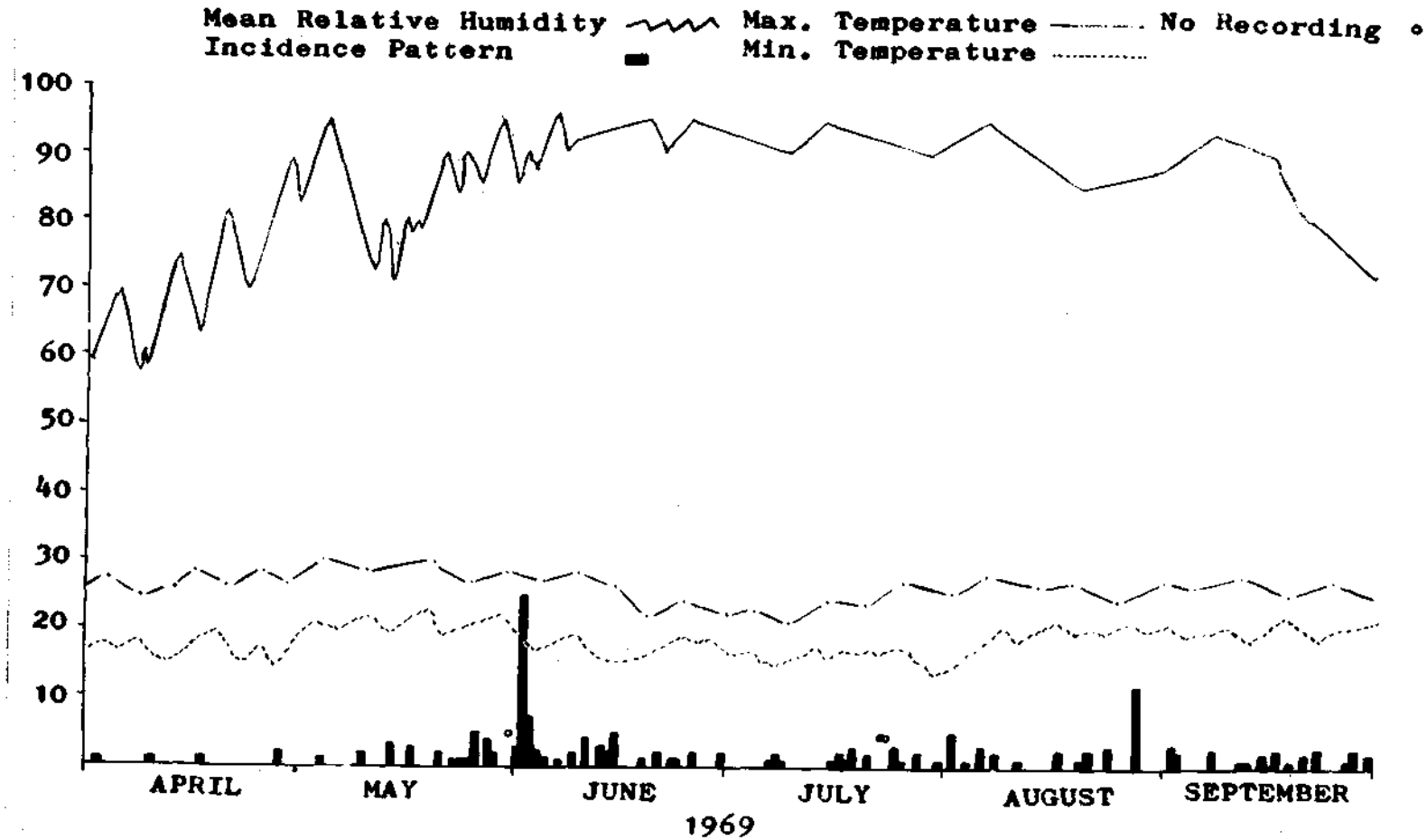

FIG.27: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Gomphostilbia) tenuistylum, n.sp. on the abscissa, at Darjeeling Government College collecting Station from April - September, 1969. Figures on the ordinate indicate quantity

abruptly, and subsequently the incidence was uniform but poor. There was, however, a small sub-ordinate peak with only 11 specimens on 10.9.69. The average nightly turn-up of the species was 2.66 specimens in May; 1.03 specimens in June; 0.69 in July; 0.55 in August; 1.07 in September; and 1.02 specimens for the whole period.

The peak abundance of rufibasis was seen in the last part of June with trapping of 24 specimens on 24.6.69. The peak was attained very abruptly, the catch-rate of the species being very poor both in April and May, and the population declined almost steadily. In September, the population showed a sub-ordinate peak with 12 specimens on 20.9.69. The average catch-rate per night was 2.4 specimens in June; 1.83 in July; 0.45 in August; 1.37 in September; and 1.08 in the whole period.

S.(G.) tenuistylum was practically unrepresented in April, with trapping of only 5 specimens on the whole. The peak was attained abruptly on 2.6.69, with 25 specimens representing the maximum for any single night, the catch-rate for May being very poor. In the succeeding period the population also showed an abrupt decline, though in August a sub-ordinate peak, with 12 specimens recorded on 28.8.69, was observed. The nightly average turn-up of the species was 0.83 specimens in May; 2.13 in June; 0.7 in July; 1.03 in August; 0.9 in September; and 0.96 specimens for the whole period.

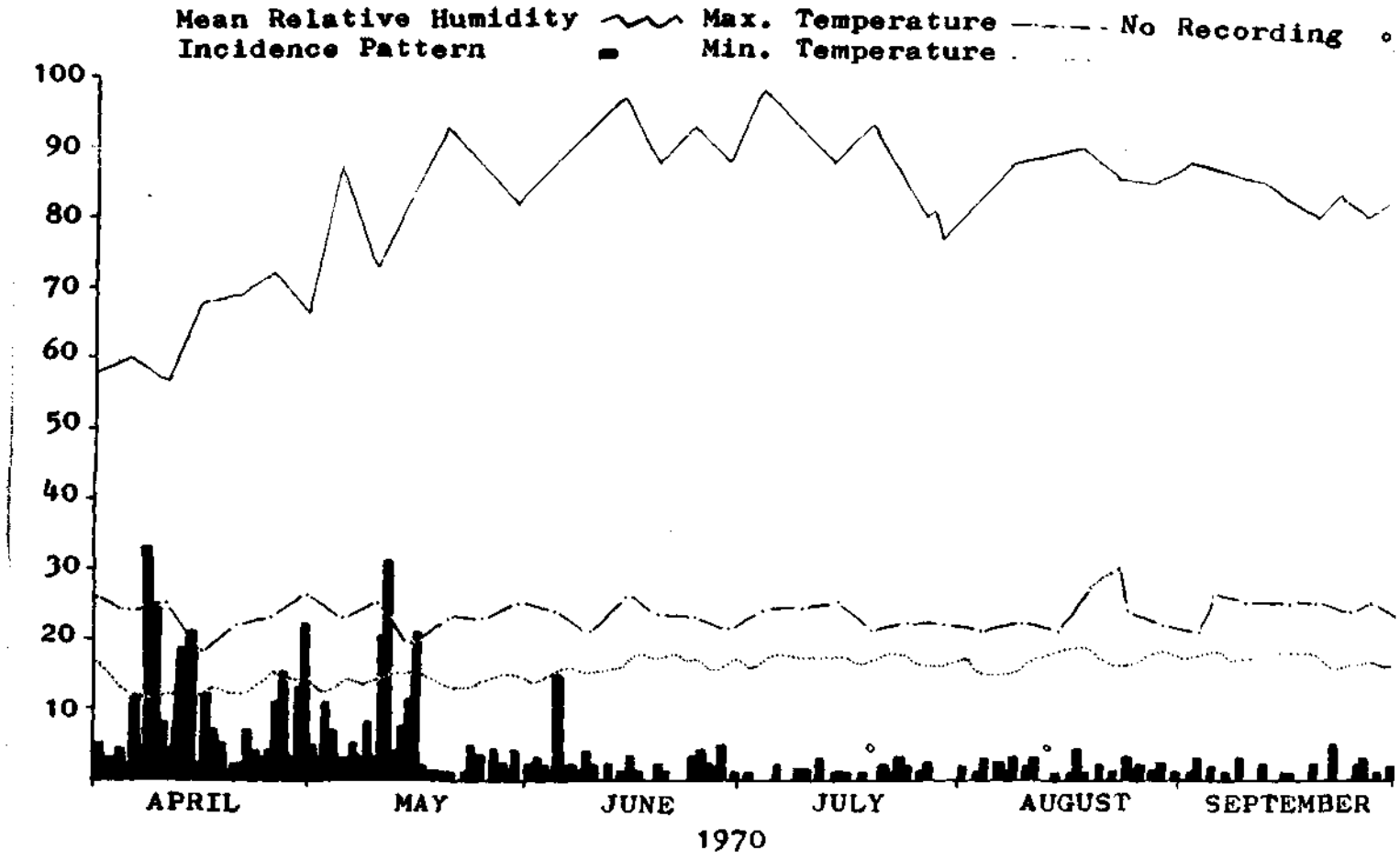

FIG.28: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Eusimulium) praelargum, n.sp. on the abscissa, at Darjeeling Government College collecting Station from April - September 1970. Figures on the ordinate indicate the quantity

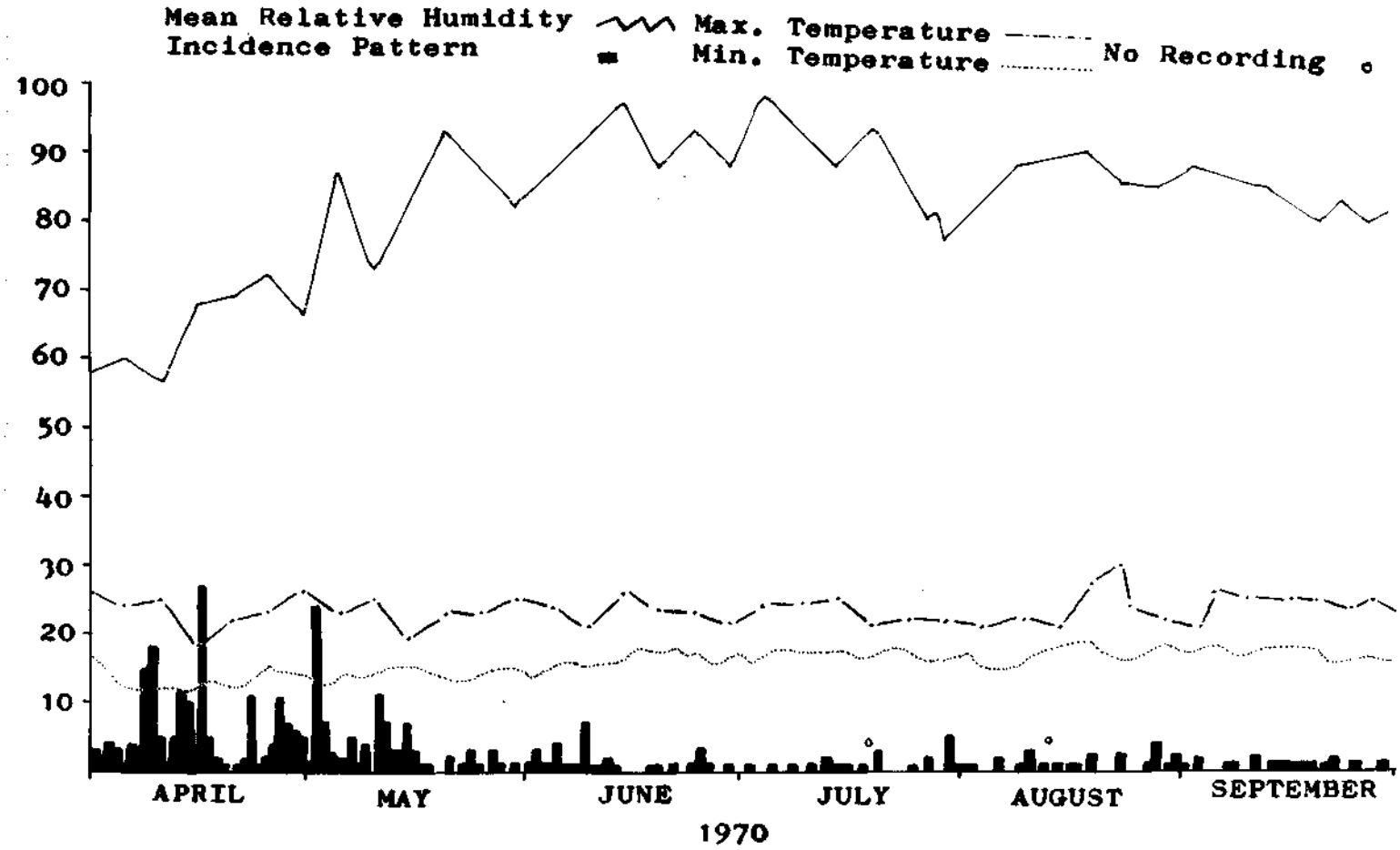

FIG.29: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Eusimulium) gracilis n.sp. on the abscissa, at Darjeeling Government College collecting Station from April - September 1970. Figures on the ordinate indicate the quantity

The above incidence patterns of the six species of black flies of the study area and within the study period are illustrated along with the patterns of the existing relative humidity and atmospheric temperature in the Figs. 22-27.

(c) Seasonal incidence in 1970

The peak abundance of praelargum was shown on 8.4.70, with the trapping of 33 specimens, which represented the maximum for any single night. The population, through a number of rise and fall, began to decline by the middle of June. The last rise (recorded on 5.6.70) with 15 specimens only, was seen a little after the last part of May. The average nightly turn-up of the species was 8.67 specimens in April; 5.52 in May; 2 in June; 1.23 in August; 0.8 in July; 0.97 in September; and 3.21 in the whole period.

S.(E.) gracilis showed a similar trend of incidence pattern as shown by the former species, attaining its principal peak with 27 specimens recorded on 16.4.70., and a further rise with 24 specimens recorded on 2.5.70., following a short decline. The incidence in July, August and September was very poor. The nightly average catch of the species was 5.7 specimens in April; 3.13 specimens in May; 1.13 in June; as compared with 2.02 specimens for the whole period.

S.(S.) himalayense attained its peak in the middle of May, with 60 specimens recorded on 16.5.70, being the maximum for

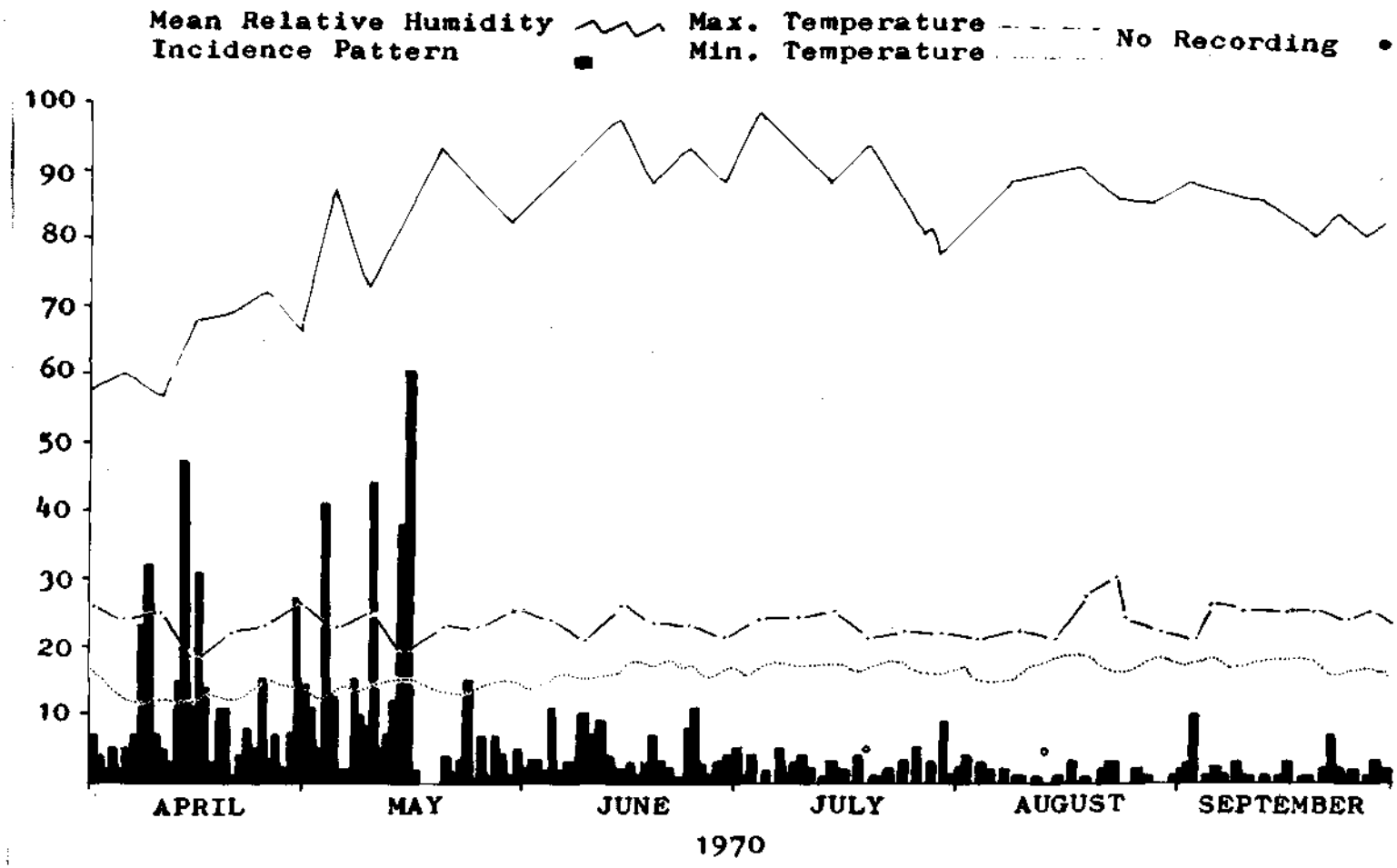

FIG.30: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Simulium) himalayense Puri (1932) on the abscissa, at Darjeeling Government College collecting Station from April - September, 1970. Figures on the ordinate indicate quantity

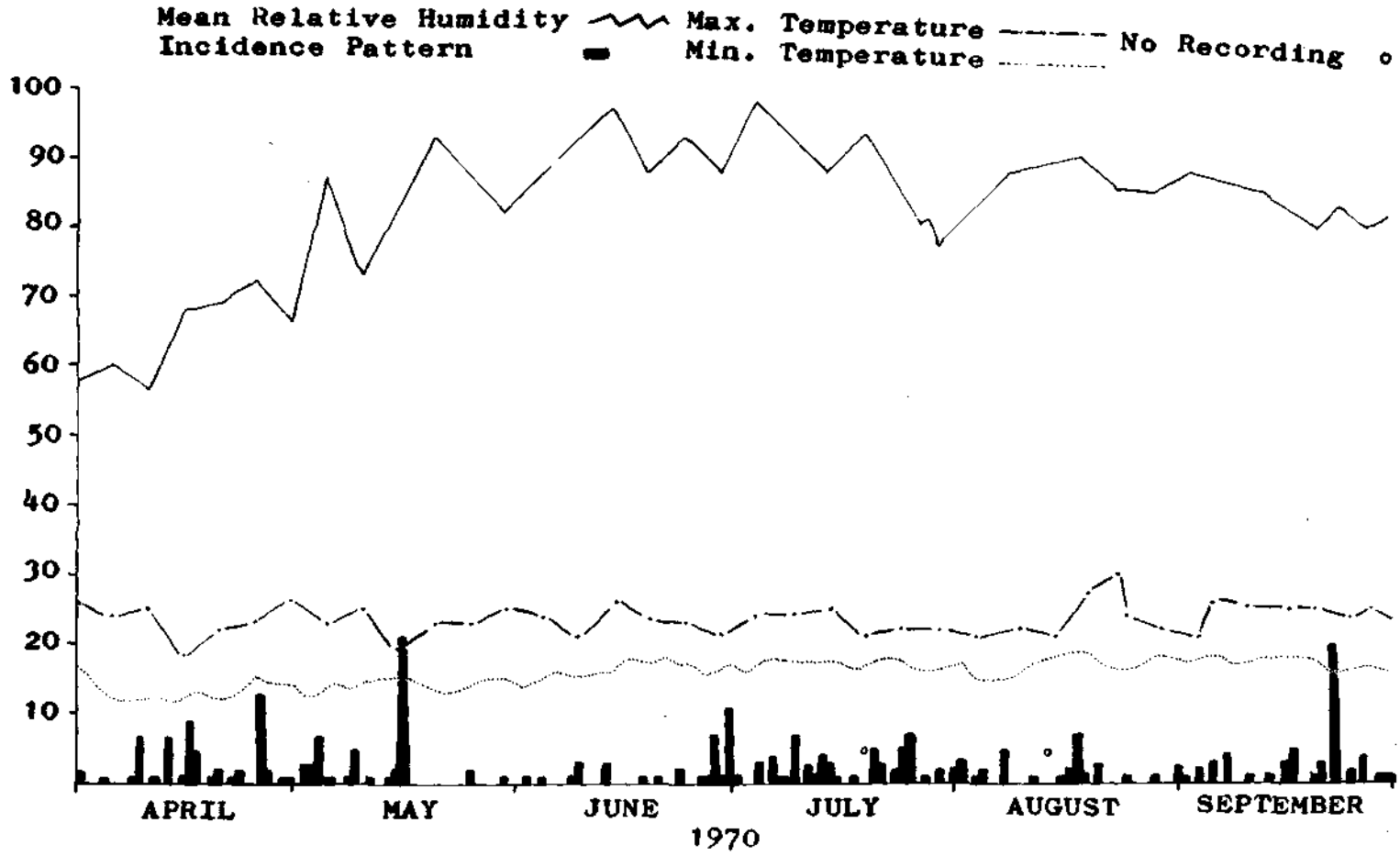

FIG.31: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Simulium) grisescens Brunetti (1911) on the abscissa, at Darjeeling Government College collecting Station from April - September, 1970. Figures on the ordinate indicate quantity

any single night. This peak was attained through a number of rise and fall in incidence, from the beginning of April, and after this peak, the population went down abruptly. In September, however, there was a very small sub-ordinate peak, with 12 specimens on 3.9.70., this being the maximum for any single night of the month. The average nightly catch of the species was 10.53 specimens in April; 10.7 in May; 3.93 in June; 2.13 in July; 1.17 in August; 1.23 in September;in comparison with 5.09 for the whole period.

The population of grisescens attained its peak on 16.5.70, with 21 specimens. In the preceding period the incidence was gradual, but irregular. In the succeeding period the population fell down abruptly after the principal peak, and it rose again from the last part of June, and on 22.9.70, a sub-ordinate peak was encountered. The nightly average turn-up of the species was 1.83 specimens in April; 1.63 in May; 1.13 in June; 1.87 in July; 1 in August; 1.77 in September; and 1.53 for the whole period.

The peak of rufibasis was observed in the middle of June, with 26 specimens recorded on 19.6.70. The incidence in April was very high with a number of rise and fall, and it was maintained upto the middle of May. The principal peak was attained almost abruptly. The incidence of the following months was almost constant with a little rise in September, wherein two sub-ordinate peaks - one on 3.9.70, with 11 specimens, and the other

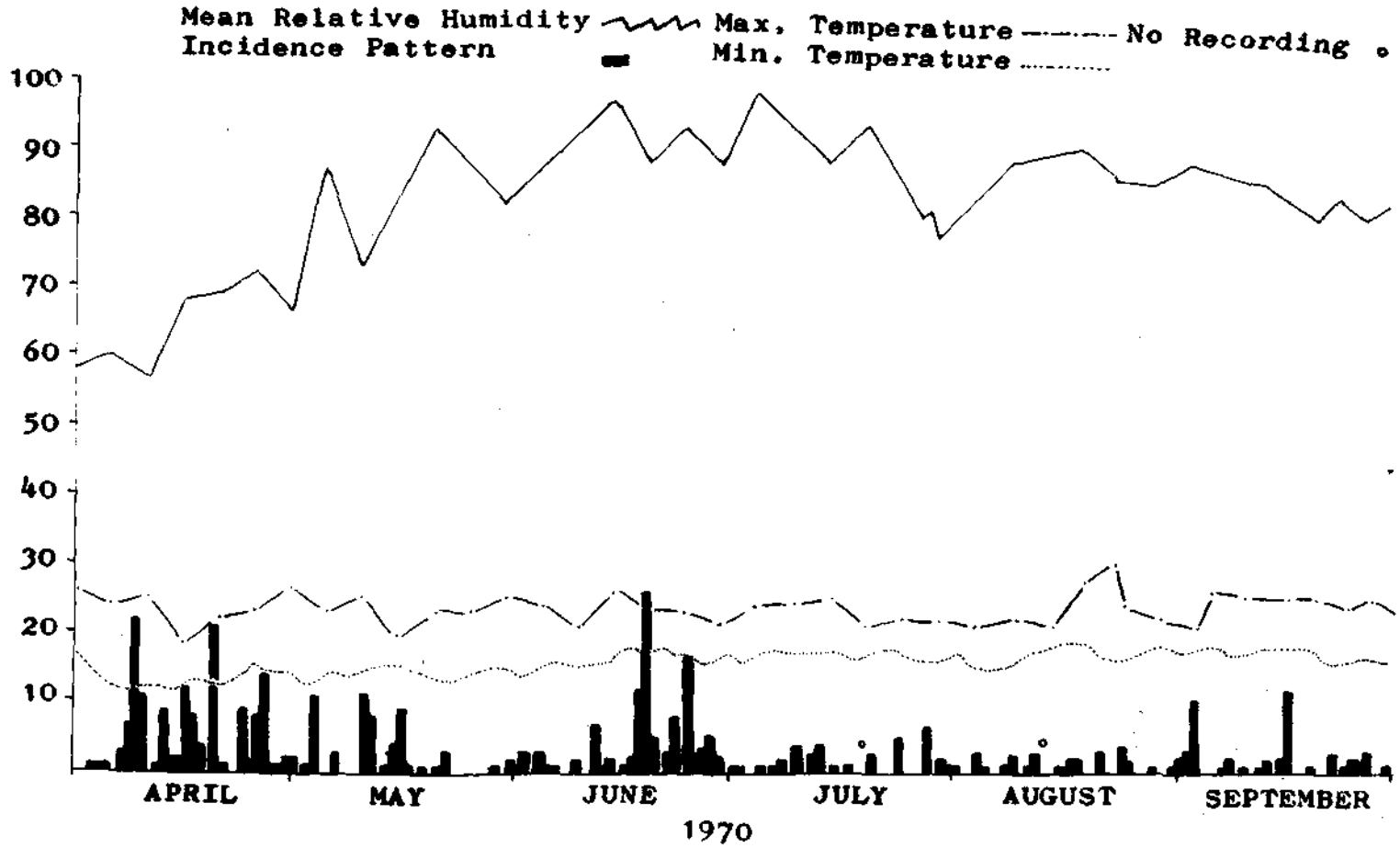

FIG.32: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Simulium) rufibasis Brunetti (1911) on the abscissa, at Darjeeling Government College collecting Station from April - September, 1970. Figures on the ordinate indicate quantity

through the following months. In the preceding period there

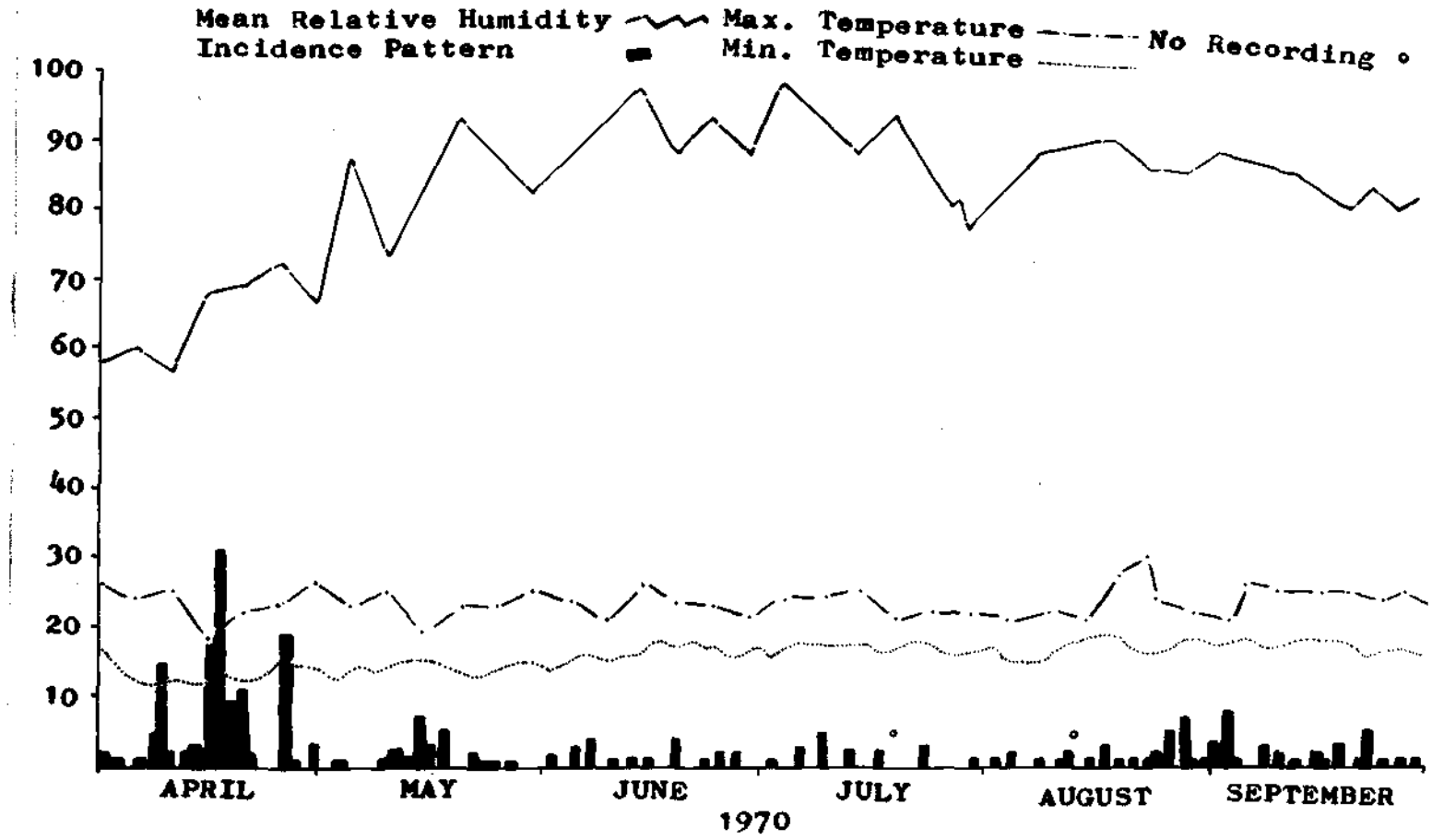

FIG.33: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Gomphostilbia) tenuistylum, n.sp. on the abscissa, at Darjeeling Government College collecting Station from April - September, 1970. Figures on the ordinate indicate quantity

on 16.9.70, with 12 specimens, were noticed. The nightly average turn-up of the species was 4.73 specimens in April; 2 in May; 3.53 in June; 1.23 in July; 1 in August; 1.63 in September; and 2.33 specimens for the whole period.

The population of tenuistylum attained its peak abruptly on 17.4.70, with the trapping of 31 specimens, and then the incidence declined steadily. The incidence was very poor both in June and July. There was higher incidence in September than in August with a sub-ordinate peak on 3.9.70., with only 8 specimens. The nightly average catch of the species was 4.4 specimens in April; 0.9 in May; 1 in August; 1.17 in September; and 1.45 in the whole period.

The incidence patterns of the six species of black flies of the study area and within the study period are illustrated along with the patterns of the existing relative humidity and atmospheric temperature in Figs. 28-33.

(d) Seasonal incidence in average

S.(E.) praelargum showed two co-ordinate peaks, with 15.7 specimens on May 11 and May 12, and then the population went down abruptly and maintained itself almost constantly through the following months. In the preceding period there were a number of rise and fall from the beginning of April.

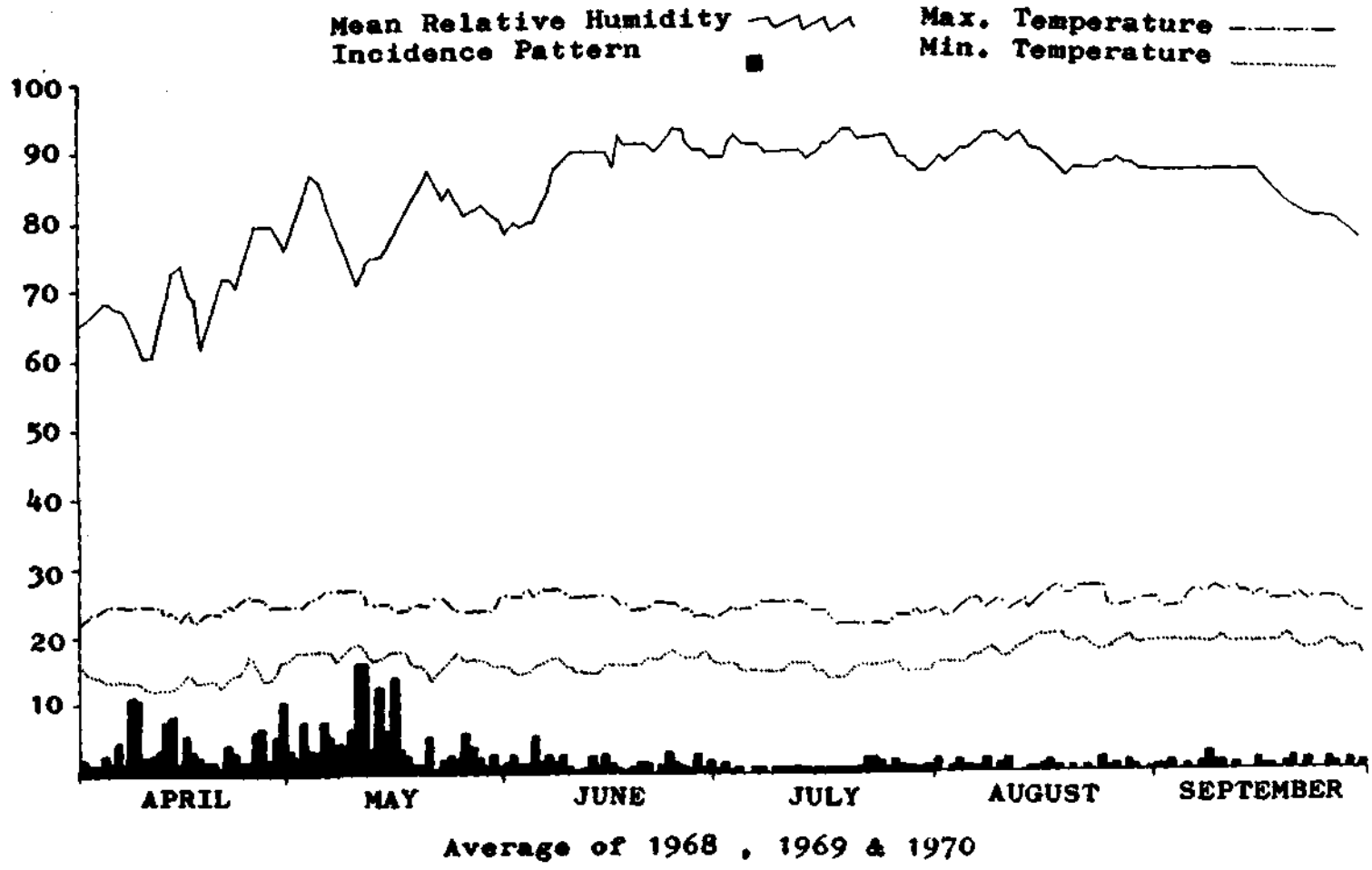

FIG.34: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Eusimulium) praelargum n.sp. on the abscissa, at Darjeeling Government College collecting Station from April - September of 1968, 1969 and 1970 (in average). Figures on the ordinate indicate the quantity

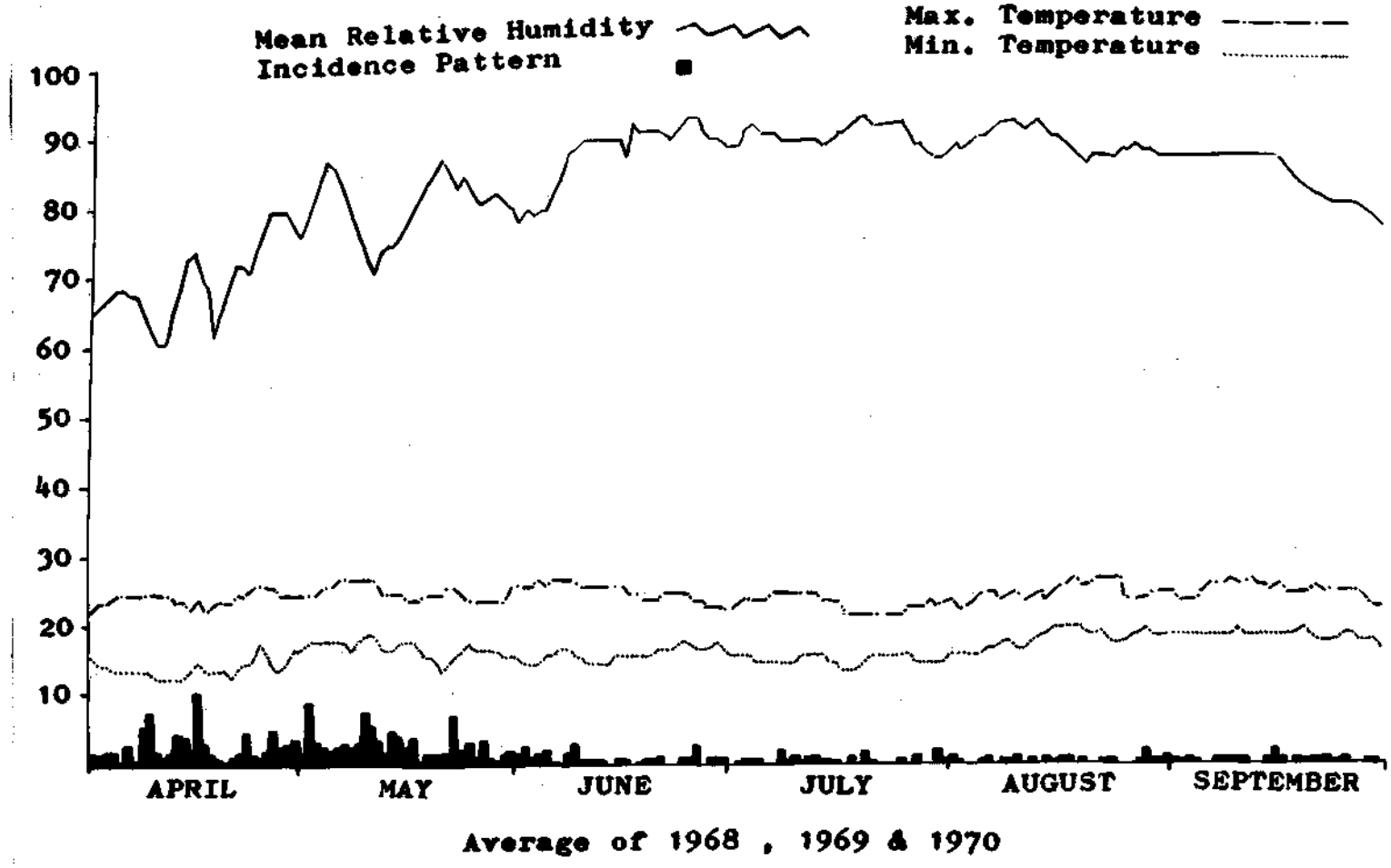

FIG.35: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Eusimulium) gracilis, n.sp. on the abscissa, at Darjeeling Government College collecting Station from April - September of 1968, 1969 and 1970 (in average). Figures on the ordinate indicate the quantity

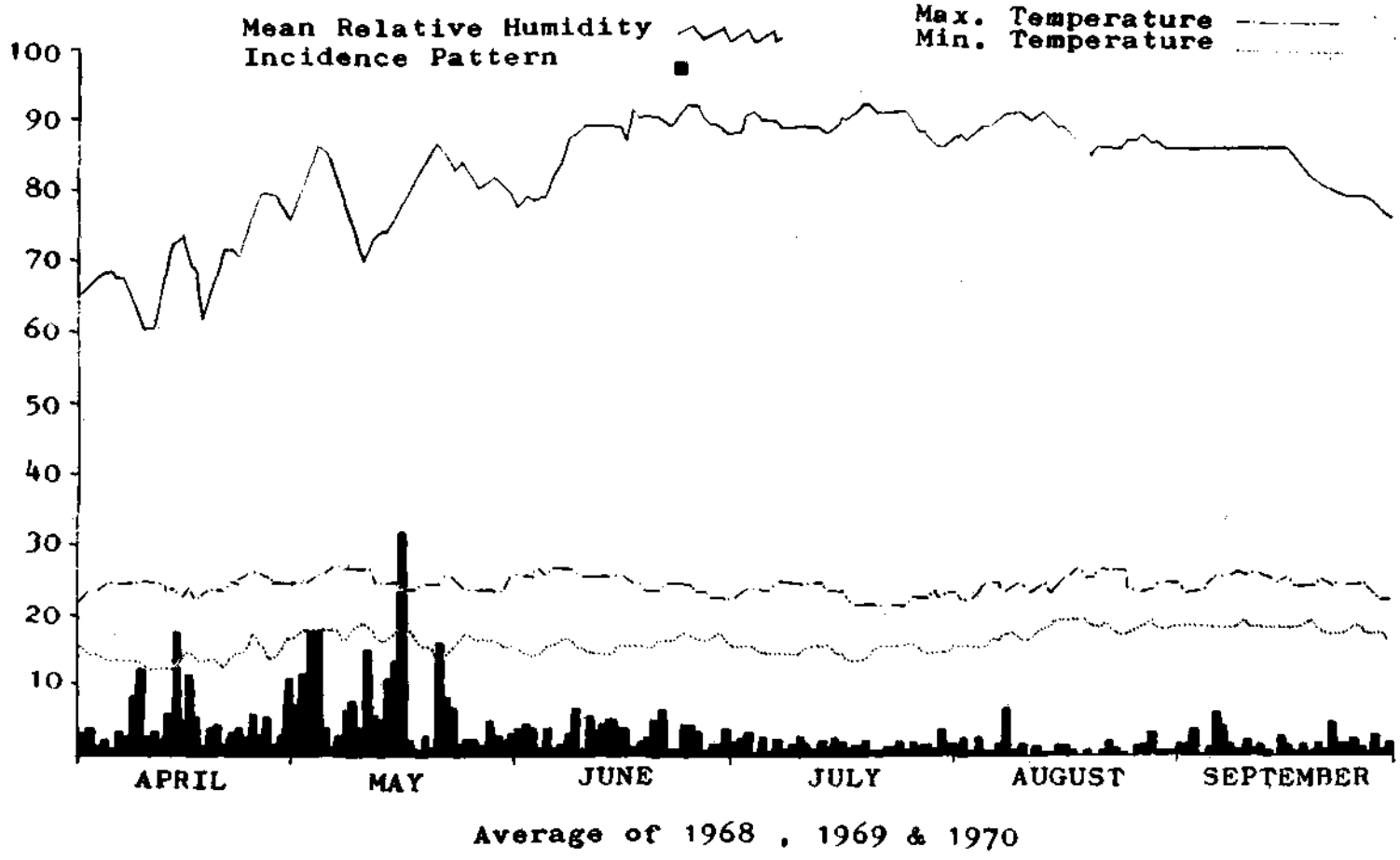

FIG.36: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Simulium) himalayense Puri (1932) on the abscissa, at Darjeeling Government College collecting Station from April - September of 1968, 1969 and 1970 (in average). Figures on the ordinate indicate the quantity

S.(E.) gracilis showed its principal peak on April 16 with only 10.3 specimens. The incidence of the species was higher in April and May, with rise and fall, than in the following months.

The peak of himalayense was observed on May 16, with 31.5 specimens, and this peak was attained through rise and fall from the beginning of April. Subsequent to the principal peak the pupulation declined abruptly and maintained itself almost constantly. In September, however, there was a rise in incidence of the population.

The population of grisescens showed the peak on June 16, with 13 specimens, and then gradually it went down through the following months, except in September, when there was a rise in incidence. The incidence in April was poor, and in May there was a rise in the incidence in the last half of the month.

S.(S.) rufibasis attained its peak with 16.3 specimens on June 13, and then the population gradually declined. In September the incidence was again on the verge of ascent. The incidence, both in April and in May, maintained itself almost constantly.

The peak abundance shown by tenuistylum was on April 17 with 11 specimens, and then the population maintained itself almost constantly upto the first part of June with a little rise

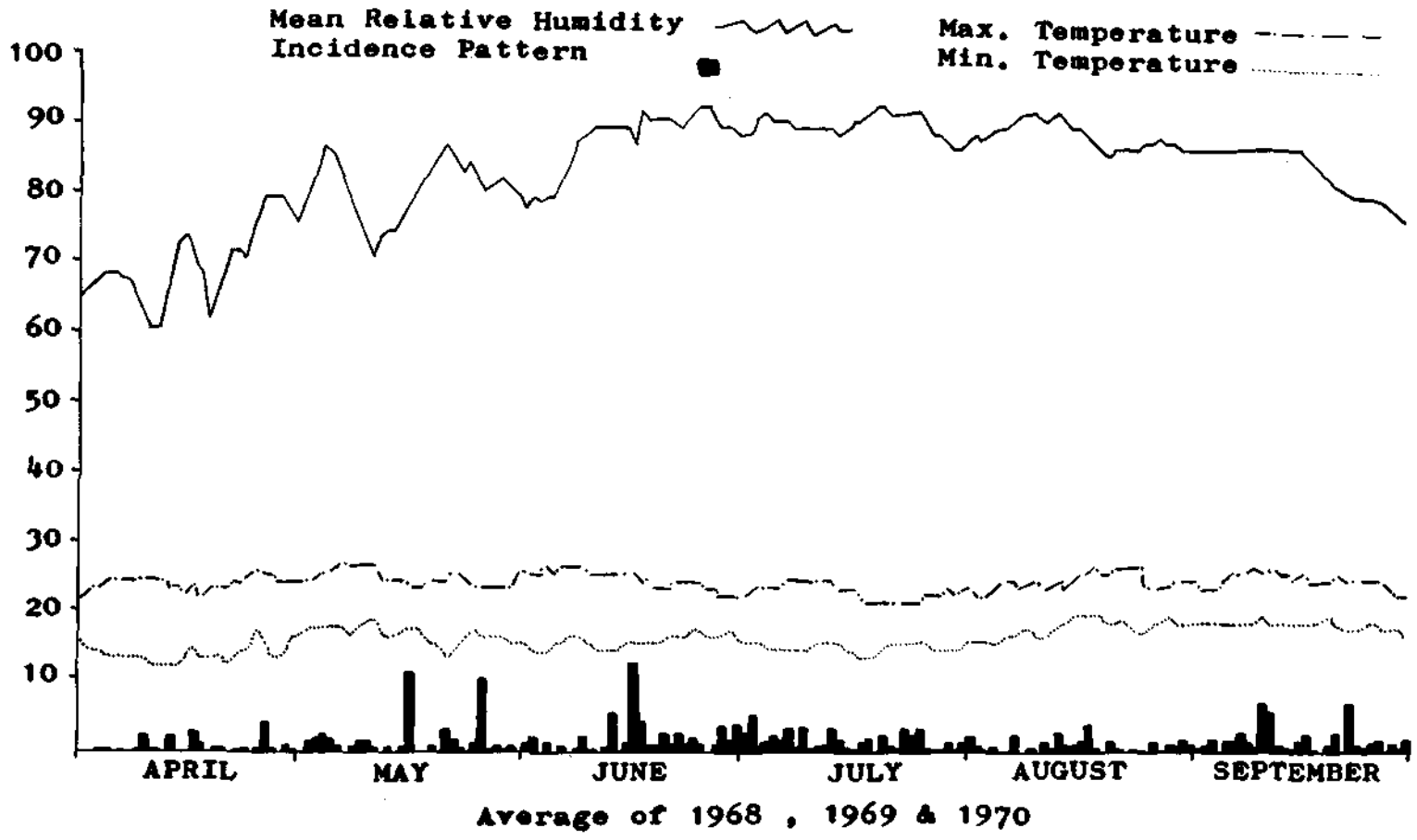

FIG.37: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Simulium) grisescens Brunetti (1911) on the abscissa, at Darjeeling Government College collecting Station from April - September of 1968, 1969 and 1970 (in average). Figures on the ordinate indicate the quantity

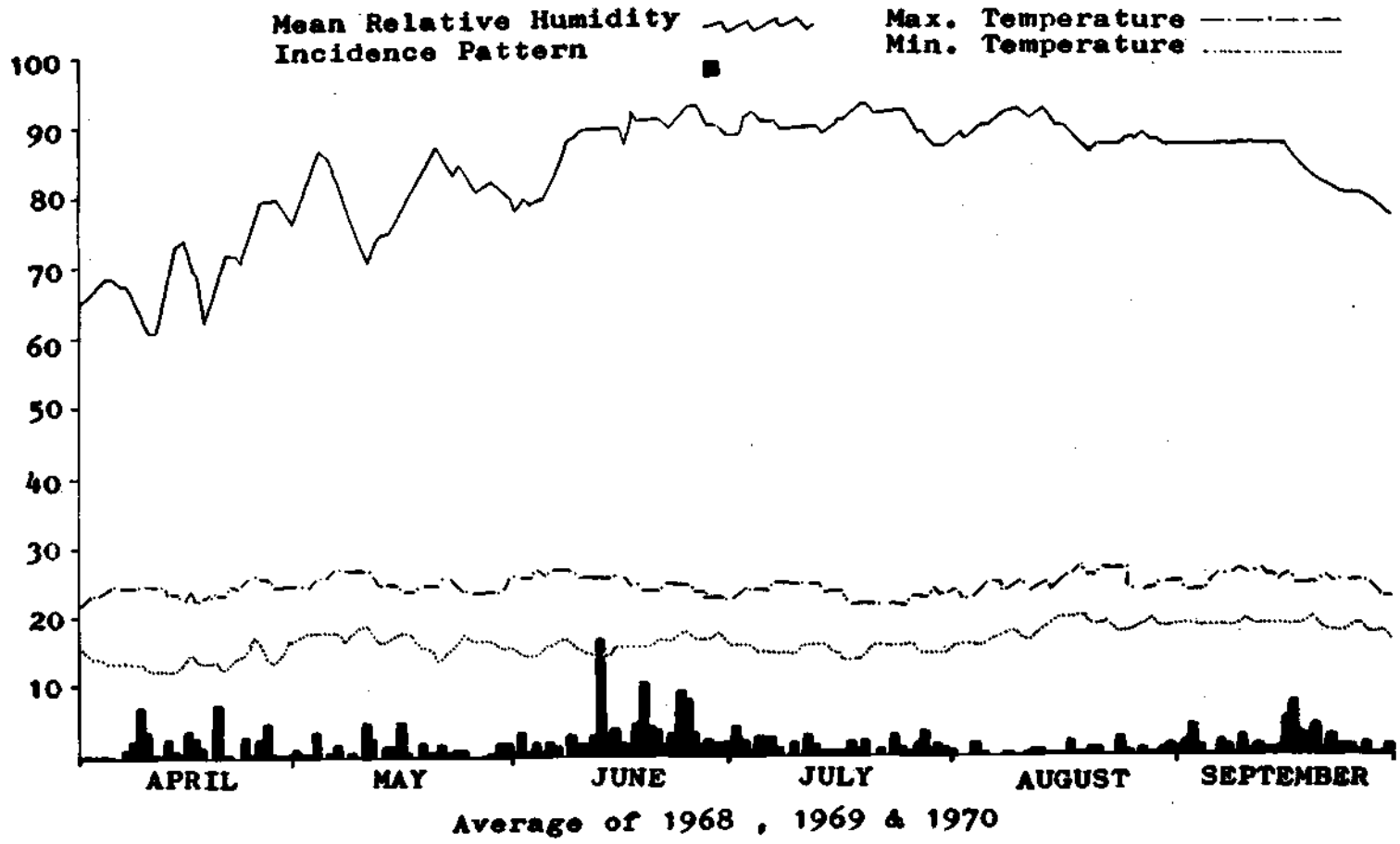

FIG.38: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Simulium) rufibasis Brunetti (1911) on the abscissa, at Darjeeling Government College collecting Station from April - September of 1968, 1969 and 1970 (in average). Figures on the ordinate indicate the quantity

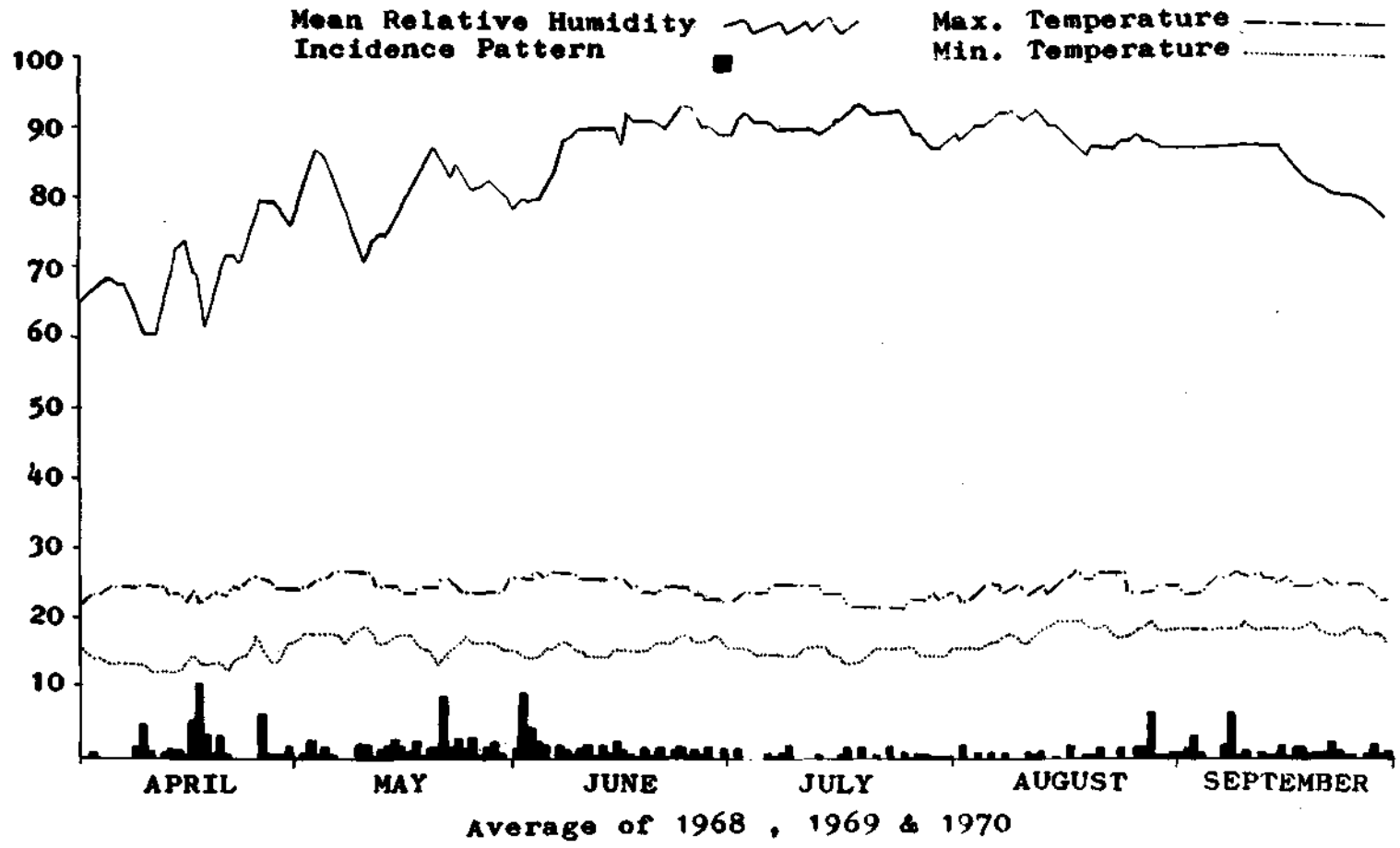

FIG.39: The mean relative humidity, maximum and minimum temperatures, and daily catches of Simulium (Gomphostilbia) tenuistylum n.sp. on the abscissa at Darjeeling Government College collecting Station from April - September of 1968, 1969 and 1970 (in average). Figures on the ordinate indicate the quantity

in incidence though the population was very low. From the end of August the population again began to rise to a considerable extent.

The above incidence patterns of the six species of black flies of the study area and within the whole study period are illustrated along with the patterns of the existing relative humidity and atmospheric temperature (in average)in Figs. 34-39.

Seasonal succession

The peak abundance analysed above showed the seasonal succession of the six species of black flies of the present study. Those months having at least one specimen per day (i.e., 30 specimens for 30 days comprising a month) were considered to be the months of their abundance. In this way in 1968 (Fig.-40) praelargum was abundant from April to June with peak in the early May; S.(E.) gracilis only in May with the peak in the late May; S.(S.) himalayense throughout the study period except August, with the peak in the early May; S.(S.) grisescens from June to September, with the peak in the middle of June; S.(S.) rufibasis in June, July and September, with the peak in the middle of June and tenuistylum in the months of May, June and September, with the peak in late May.

In 1969 (Fig.-41), praelargum showed abundance only in April and May, with the peak in the middle of May; S.(E.) gracilis showed the same type of abundance but the peak was in

the early part of May; S.(S.) himalayense in the whole study period with the peak in late May; S.(S.) grisescens in May, June and September, with the peak in late May; S.(S.) rufibasis in June, July and September, with the peak in late June; and tenuistylum in June and August, with the peak in early June.

In 1970 (Fig.-42), the abundance of praelargum was in April, May, June and August, with the peak in the early April; that of gracilis was in April, May and June with the peak in the middle of April; that of himalayense in the whole study period, with the peak in the middle of May; that of grisescens in the whole study period as of the former species, with the peak in the same period; that of S.(S.) rufibasis in the same period except August, but the peak was in the last part of June; and that of tenuistylum in April, August and September, with the peak almost in the last part of April.

In average (Fig.-43), praelargum showed abundance from April to June with the peak in the early part of May; S.(E.) gracilis only in April and May, with the peak in the middle of April; S.(S.) himalayense in the whole study period, with the peak in the middle of May; S.(S.) grisescens in the whole study period except April with the peak in the middle of June; S.(S.) rufibasis in the whole study period except August, with the peak in about the middle of June, and S.(G.) tenuistylum from April to June and September with the peak in the middle of April.

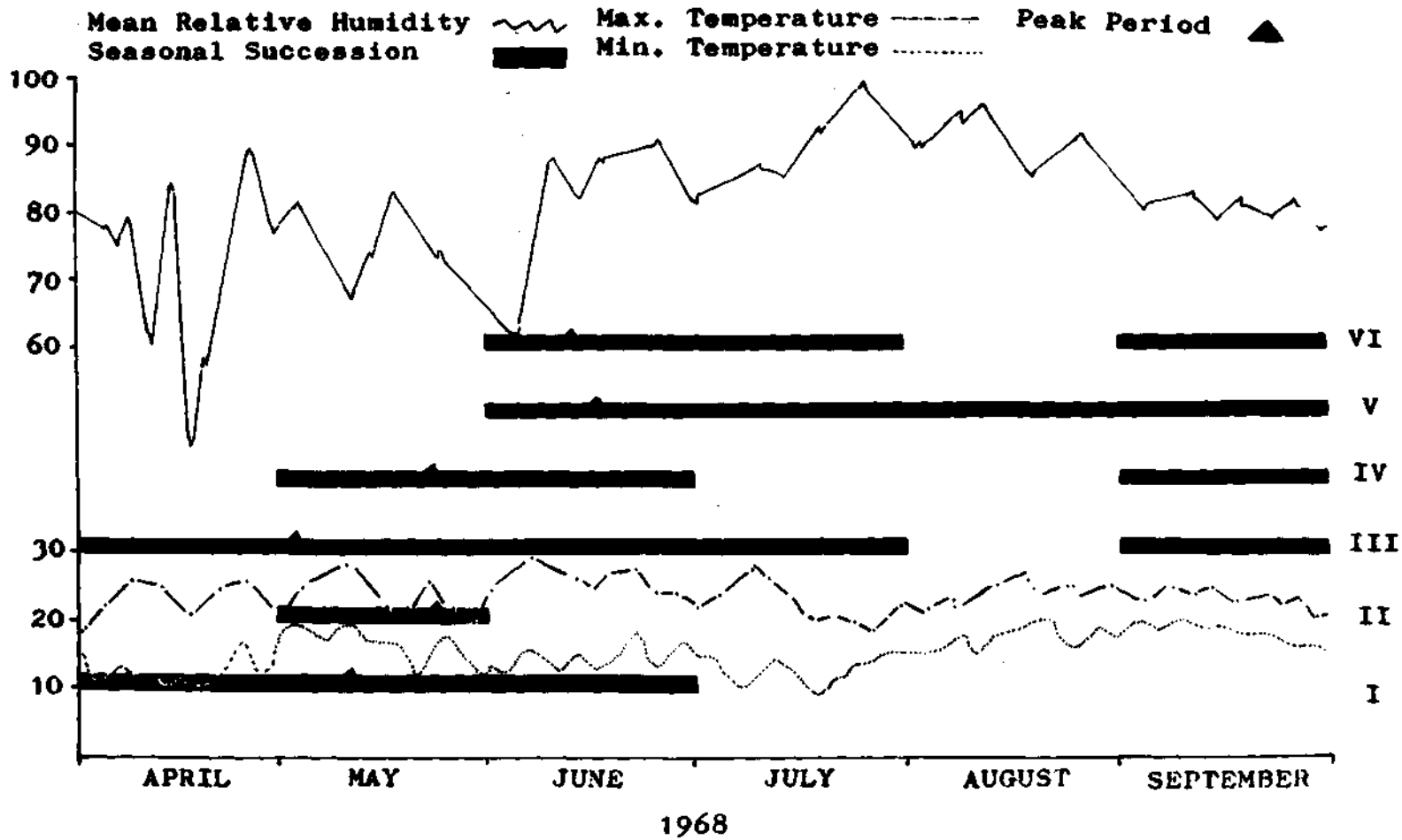

FIG.40: Seasonal succession of black flies, Simulium (Eusimulium) praelargum n.sp. (I), S.(E.) gracilis n.sp. (II), Simulium (Simulium) himalayense Puri(III) Simulium (Gomphostilbia) tenuistylum n.sp.(IV), S.(S.) grisescens Brunetti (V) and S.(S.) rufibasis Brunetti (VI) of the present study in 1968

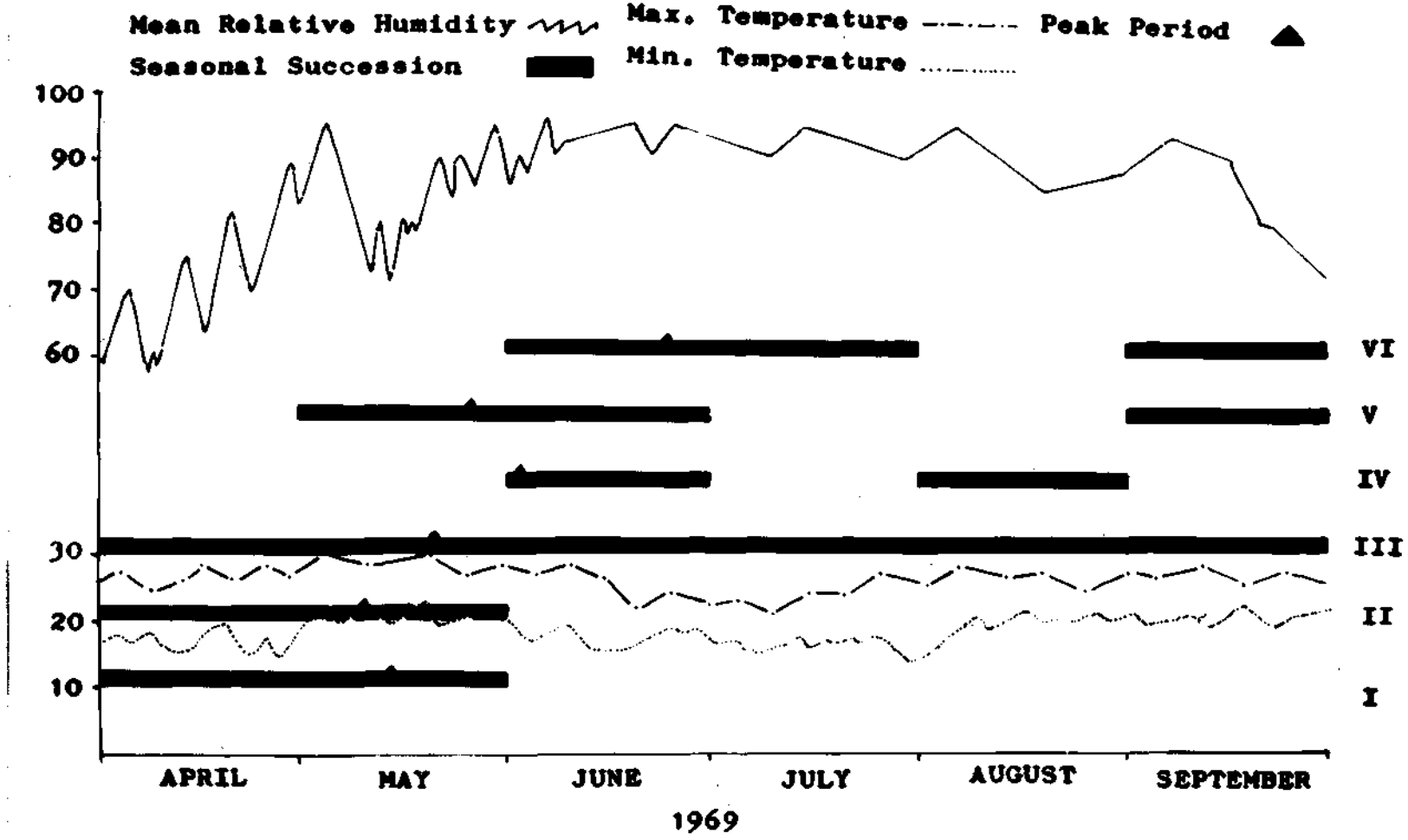

FIG.41: Seasonal succession of black flies, Simulium (Eusimulium) praelargum n.sp. (I), S.(E.) gracilis n.sp.(II), Simulium (Simulium) himalayense Puri (III) Simulium (Gomphostilbia) tenuistylum n.sp.(IV), S.(S.) grisescens Brunetti (V) and S.(S.) rufibasis Brunetti (VI) of the present study in 1969

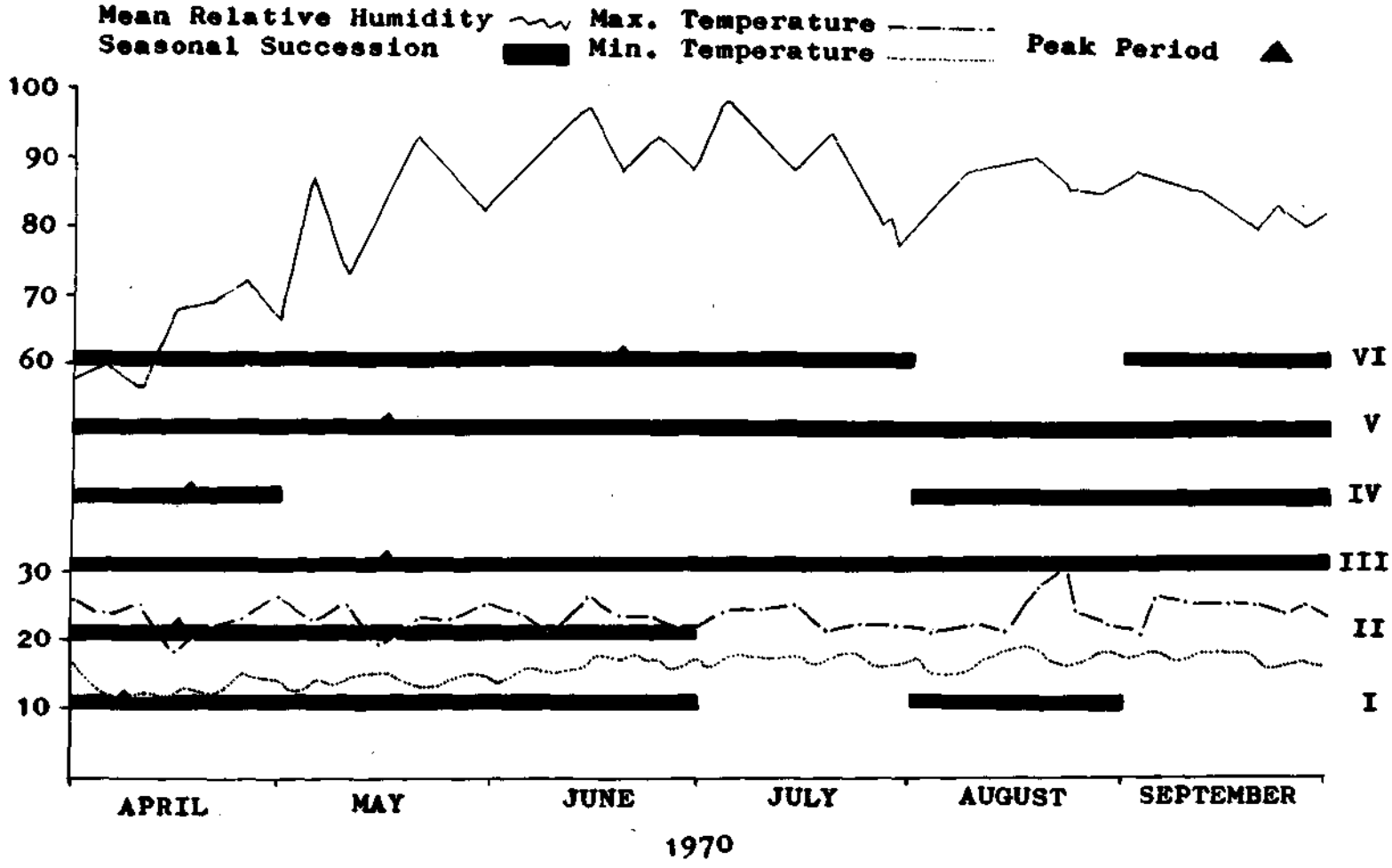

FIG.42: Seasonal succession of black flies, Simulium (Eusimulium) praelargum n.sp. (I), S.(E.) gracilis n.sp.(II), Simulium (Simulium) himalayense Puri (III) Simulium (Gomphostilbia) tenuistylum n.sp. (IV), S.(S.) grisescens Brunetti (V) and S.(S.) rufibasis Brunetti (VI) of the present study in 1970

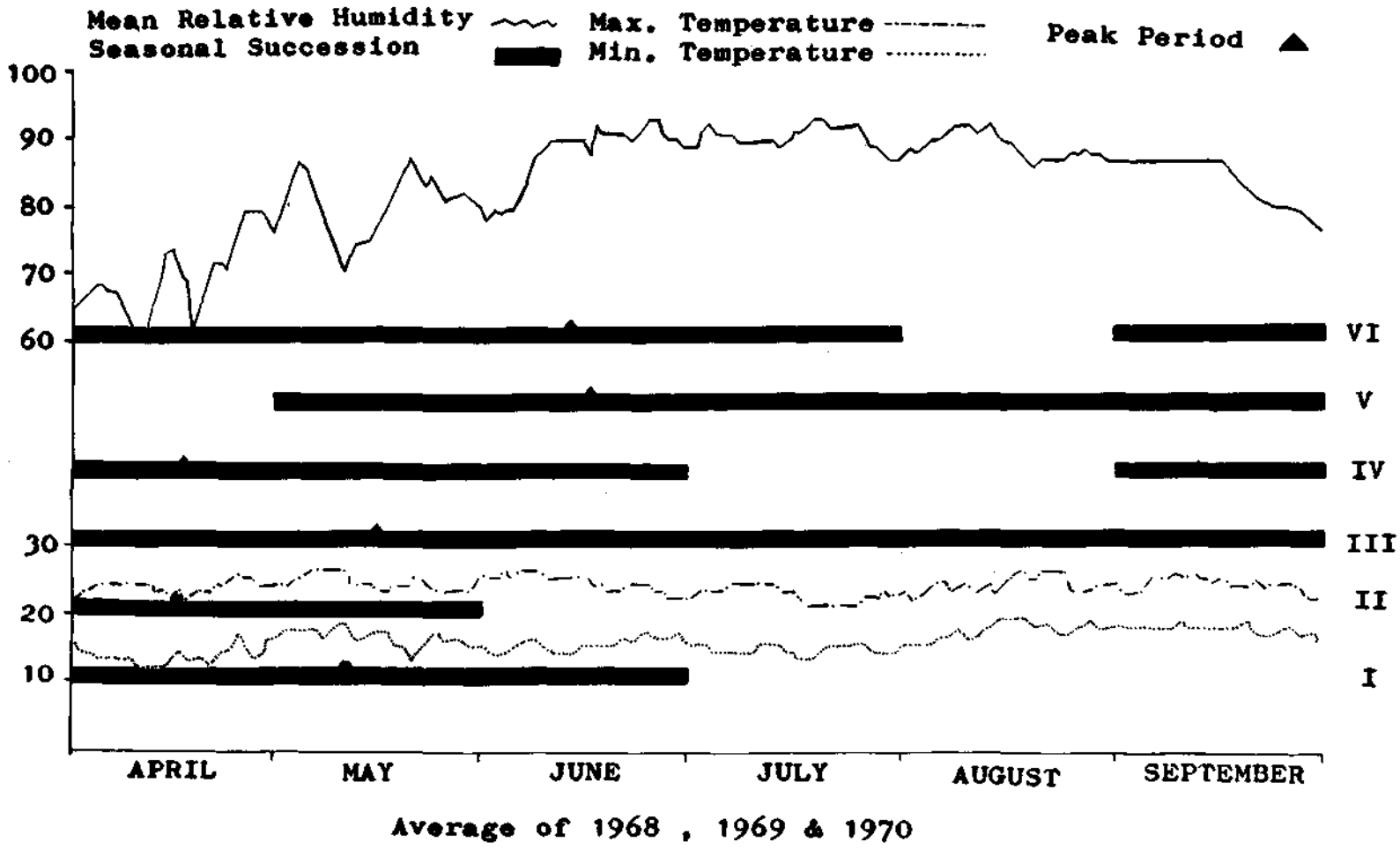

FIG.43: Seasonal succession of black flies, Simulium (Eusimulium) praelargum n.sp. (I), S.(E.) gracilis n.sp. (II), Simulium (Simulium) himalayense Puri(III) Simulium (Gomphostilbia) tenuistylum n.sp.(IV), S.(S.) grisescens Brunetti (V) and S.(S.) rufibasis Brunetti (VI) of the present study in average of 1968, 1969 and 1970.

Discussion

The great abundance of himalayense in contrast to other species of the subgenus Simulium taken in the light trap was probably due to the occurrence of a good number of suitable breeding centres along with certain other favourable conditions in the vicinity of the trapping site. The very low catch recorded in August, 1968 was due to the disturbance of the breeding centres on account of heavy rainfall and extensive land-slides in 1968. The abundance of rufibasis was slightly higher than that of grisescens. Both these species showed the tendency to become abundant after himalayense, except in 1970, when there was almost a similar distribution pattern. The pattern for 1970 might be accepted as the normal pattern as in this year there was no natural disaster. The year 1969 might be called the preparatory year for the high incidence recorded in 1970 following the natural calamity in 1968, when practically all of the breeding sites were destroyed during the rainy season and this might explain the variation in population-size during the whole study period. A similar situation was also reported by Wolfe and Peterson (1959) during their field studies in Quebec.

S.(E.) praelargum and gracilis were apparently the earlier species to occur, having appeared presumably in the last part of March or in early part of April. S.(G.) tenuistylum probably appeared later than the former two species. The devious nature

of incidence shown by all these species of black flies was perhaps responsible for the irregularity in the attainment to a certain population level in the area of trapping. The actual dates of the first appearance of these flies could not be pinpointed due to lack of information regarding the overwintering stages of these flies.

Davies and Williams (1962) in Scotland held that a light trap would not be expected to produce the same time-distribution picture in a given species as that from observations on the aquatic stages, and that such a trap would be expected to show some indications of successive generations by the presence of peaks and troughs in the catch size. As recorded in 1970, the adults of all the species, which showed the first peak abundance from April to June, might be the product of the overwintered larvae, and the adults showing second peak abundance in August or September, or later, might produce the overwintering larvae in the species of the subgenera Simulium and Gomphostilbia. The species of those subgenera, therefore, might be the bivoltine species, while those of the subgenus Eusimulium were probably univoltine.

According to Grenier (1949), adults of Simulium ornatum Mg. in France produced from the earliest hatched eggs out of the egg-batch laid might oviposit before others had hatched in the field. This phenomenon was also found to be true by Peterson

and Wolfe (1956) and, Fredeen (1959) in Canada. The complicated nature of incidence of some species of black flies taken in the light trap in the present study might be caused by such "pipe-line effect" as discussed by Davies and Williams (1962), and the relationship of the peak abundance to voltinism in fields would hardly hold good in all the cases.

The incidence of black flies during trapping was certainly dependent upon the preceding and current weather conditions as was also reported by Williams (1951, 1961, 1962) in Scotland. According to him (Williams, 1962) the highest night-activity of black flies was effected in the minimum temperature above 6°C, in falling barometer, particularly when the pressure was already low, in the absence of rain or with quite heavy rain. In the present investigation the highest incidence was found to occur mostly in the minimum temperature above 14°C and in the maximum temperature below 26°C. Absence of wind and little or no rainfall accompanied by the relative humidity of 65%-80% were most suitable for highest incidence, though deviation was also experienced. Rubtzov (1939) observed the optimum activity in 20-23°C temperature, 75%-90% relative humidity with the absence of rain and high wind in day light during his field studies in Central Asia. In Canada, Davies (1952) found that most black flies were on the wing at 24°C-26.6°C and in the moist air; but not when it was close to saturation point. The low wind velocity was favourable. From the records of the present

investigation it was often difficult to explain the incidence of these insects in relation to all the meteorological conditions within the study period. The presence of other factors of unknown nature acting upon the incidence of these insects in the study area could not also be ruled out in the absence of evidence to the contrary.

Summary

The seasonal distribution and succession of six major species of black flies in Darjeeling were shown with the help of a simple light trap device. From the trend of incidence it was indicated that both Simulium (Eusimulium) praelargum n.sp. and S.(E.) gracilis n.sp. were the earliest species to occur almost with the departure of the winter. Simulium (Gomphostilbia) tenuistylum n.sp. was apparently found to appear just after the former two species almost simultaneously with Simulium (Simulium) himalayense Puri (1932a). The other two species, S.(S.) grisescens Brunetti (1911) and S.(S.) rufibasis Brunetti (1911) were the later species to show their peak abundance in last part of May or June.

All the species except the species of the subgenus Eusimulium showed a little rise in incidence before the advent of the winter indicating the bivoltine nature of the species.

The highest incidence was recorded mostly in the minimum temperature above 14°C and in the maximum temperature below 26°C. Absence of wind and little or no rainfall accompanied by the relative humidity of 65%-80% were most suitable for highest incidence.

The relationship of incidence of black flies taken in the light trap with their life-cycles in fields, and their deviations from the normal pattern are discussed in details.

SEX-RATIO

Introduction

Notwithstanding the behavioural variations in both sexes of insects it is customary to study the sex-ratio of insects obtained by light trapping in order to show certain aspects of insects' life intimately associated with the proportions of sexes of a species of insects. Davies and Williams (1962), in Scotland, showed the heterogeneity of sexes for seven species of black flies belonging to the family Simuliidae (Diptera) taken in a light trap, whereas Rubtzov (1939), during his ecological studies of black flies in some Russian localities, observed the homogeneity of sexes of each of the species studied. In Canada, Judd (1957) and Fredeen (1961) studied the bionomical phenomena of *Simulium vittatum* Zetterstedt and *S.arcticum* Malloch and held that the females consistently outnumbered the males. Even the results obtained by Williams (1964) in Scotland from light trapping data were found to tally with the above trend in average.

Method

Black flies were collected by continuous light trapping between 7 P.M. and 5 A.M. at Darjeeling Government College campus in 1790 trap-hours of 179 nights from April 1, 1968 to September 30, 1968; in 1800 trap-hours of 180 nights from April 1, 1969 to September 30, 1969; and in 1810 trap-hours of 181 nights from April 1, 1970 to September 30, 1970 with the help of a simple light trap device described in the page no.132. Male and female specimens of each of the major species of black flies trapped were assorted and counted in order to find out the sex-ratios of the trapped series.

Result

Black flies collected by the above method were found to consist of six major species, namely, Simulium (Eusimulium) praelargum n.sp., S.(E.) gracilis n.sp., Simulium (Simulium) himalayense Puri (1932a), S.(S.) grisescens Brunetti (1911), S.(S.) rufibasis Brunetti (1911) and Simulium (Gomphostilbia) tenuistylum n.sp., and a few rare species.

The frequencies of the appearance of male and female of all species of the major group are shown in the following tables (Tables XIV-XVII).

Table-XIV

Estimated sex-ratios of six species of black flies captured in the study site during April 1 - September 30, 1968

Species-population	Male-Female frequency		% data Male	% data Female	X^2-value
Whole population	815	826	49.66	50.34	0.07 *
praelargum	145	119	54.92	45.08	2.56 *
gracilis	59	72	45.04	54.96	1.29 *
himalayense	215	245	46.74	53.26	1.95 *
grisescens	130	172	43.05	56.95	5.84 **
rufibasis	146	130	52.90	47.10	0.92 *
tenuistylum	120	88	57.70	42.30	4.92 **

** Significant at 5% level but insignificant at 1% level.

* Insignificant at both the levels.

Table-XV

Estimated sex-ratios of six species of black flies captured in the study site during April 1 - September 30,1969

Species-population	Male-Female frequency		% data Male	% data Female	X^2-value
Whole population	651	728	47.21	52.79	4.50 **
praelargum	120	163	42.40	57.60	6.53 **
gracilis	116	76	60.42	39.58	8.33 ***
himalayense	147	206	41.64	58.36	9.86 ***
grisescens	103	80	56.29	43.71	2.90 *
rufibasis	90	105	46.15	53.85	1.15 *
tenuistylum	75	98	43.35	56.65	3.05 *

*** Significant at both 5% and 1% levels

** Significant at 5% level but insignificant at 1% level

* Insignificant at both the levels.

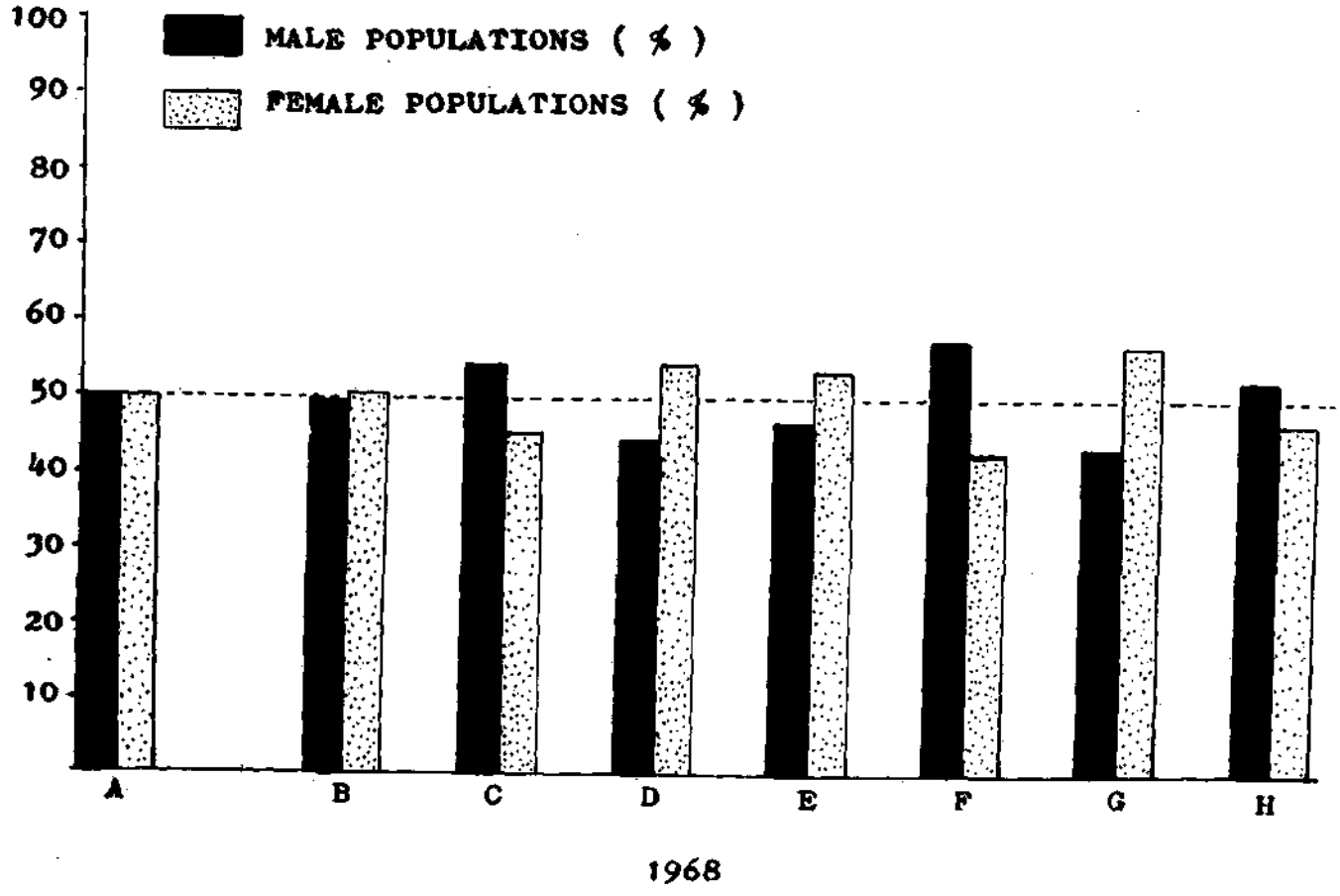

FIG.44: Histograms showing comparative catches of specimens of whole populations (B) and of Simulium (Eusimulium) praelargum n.sp. (C), S.(E.) gracilis n.sp. (D), Simulium (Simulium) himalayense Puri (E), Simulium (Gomphostilbia) tenuistylum n.sp. (F), S.(S.) grisescens Brunetti (G) and S.(S.)rufibasis Brunetti (H) of the present study in 1968, in relation to the balanced state of sex-ratio (A)

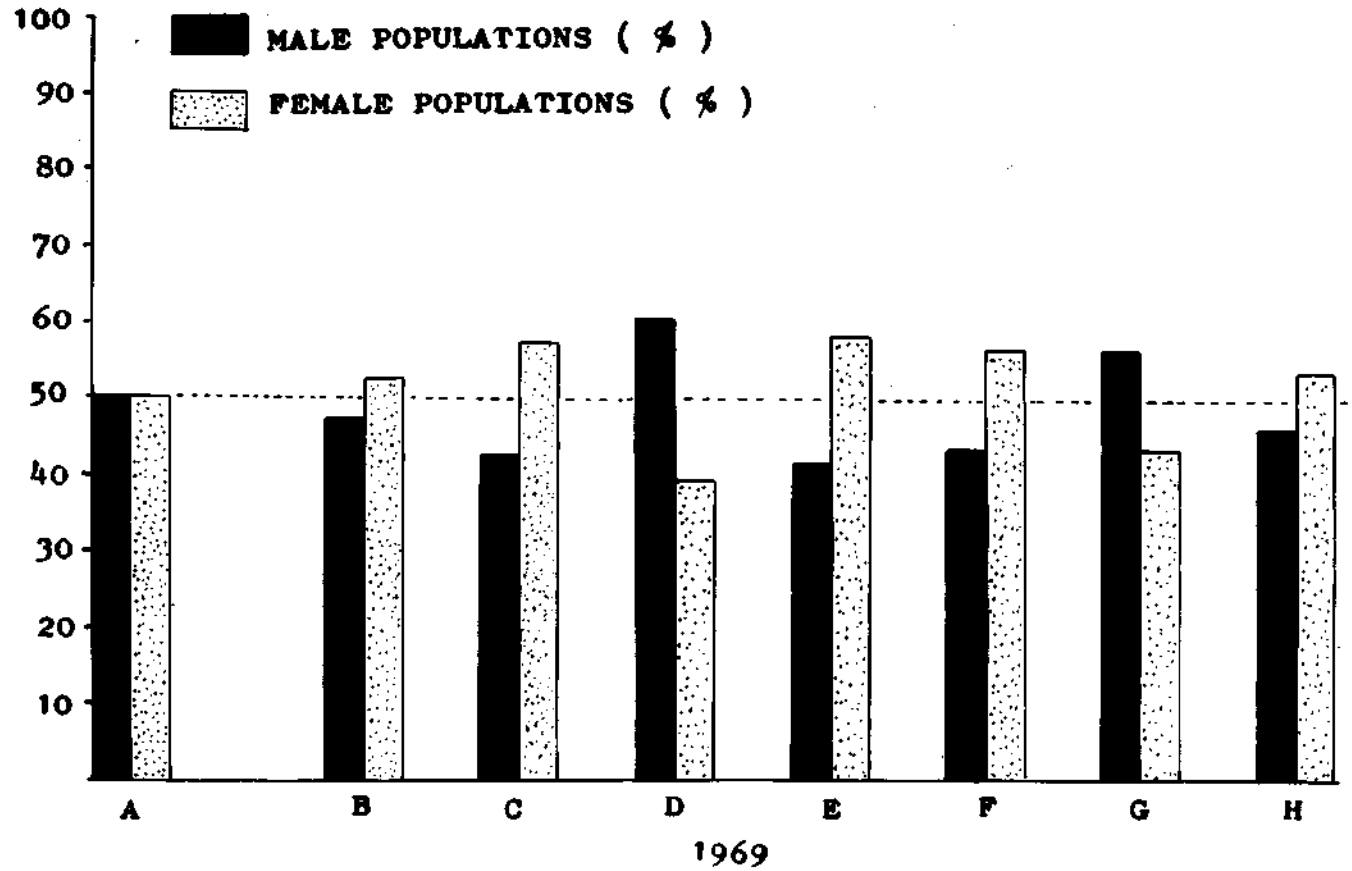

FIG.45: Histograms showing comparative catches of specimens of whole populations (B) and of Simulium (Eusimulium) praelargum n.sp.(C), S.(E.)gracilis n.sp. (D), Simulium (Simulium) himalayense Puri (E), Simulium (Gomphostilbia) tenuistylum n.sp.(F), S.(S.)grisescens Brunetti (G) and S.(S.) rufibasis Brunetti (H) of the present study in 1969, in relation to the balanced state of sex-ratio (A)

Table-XVI

Estimated sex-ratios of six species of black flies captured in the study site during April 1 - September 30, 1970

Species-population	Male-Female frequency		% data Male	% data Female	X^2-value
Whole population	1189	1639	42.04	57.96	71.29 ***
praelargum	204	377	35.11	64.89	51.51 ***
gracilis	205	160	56.16	43.84	5.54 **
himalayense	410	511	44.52	55.48	11.08 ***
grisescens	171	106	61.74	38.26	15.25 ***
rufibasis	107	315	25.35	74.65	102.50 ***
tenuistylum	92	170	35.12	64.88	23.22 ***

*** Significant at both 5% and 1% levels.

** Significant at 5% level but insignificant at 1% level.

Table-XVII

Estimated sex-ratios of six species of black flies captured in the study site during April 1 - September 30 of 1968, 1969 and 1970 (in average)

Species-population	Male-Female frequency		% data Male	% data Female	X^2-value
Whole population	885	1064	45.40	54.60	16.44 ***
praelargum	156	220	41.49	58.51	10.90 ***
gracilis	127	103	55.22	44.78	2.50 *
himalayense	257	320	44.54	55.46	6.88 ***
grisescens	135	119	53.15	46.85	1.00 *
rufibasis	114	183	38.38	61.62	16.04 ***
tenuistylum	96	119	44.65	55.35	2.46 *

*** Significant at both 5% and 1% levels.

* Insignificant at both the levels.

The patterns of sex-ratios estimated above of the trapped black flies are illustrated in the Figures 44-47.

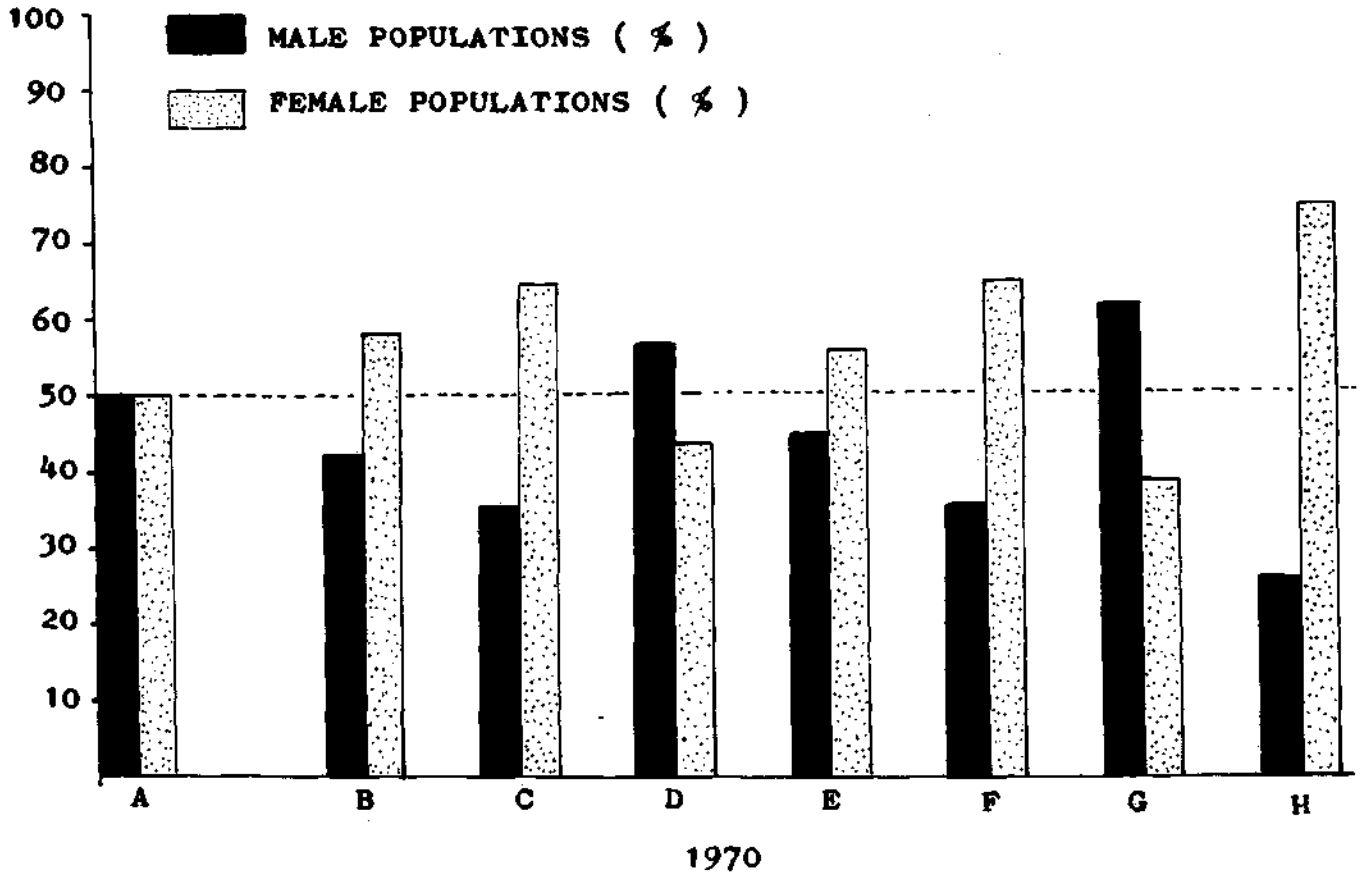

FIG.46: Histograms showing comparative catches of specimens of whole populations (B) and of Simulium (Eusimulium) praelargum n.sp.(C), S.(E.) gracilis n.sp. (D), Simulium (Simulium) himalayense Puri (E), Simulium (Gomphostilbia) tenuistylum n.sp.(F), S.(S.) grisescens Brunetti (G) and S.(S.) rufibasis Brunetti (H) of the present study in 1970, in relation to the balanced state of sex-ratio (A)

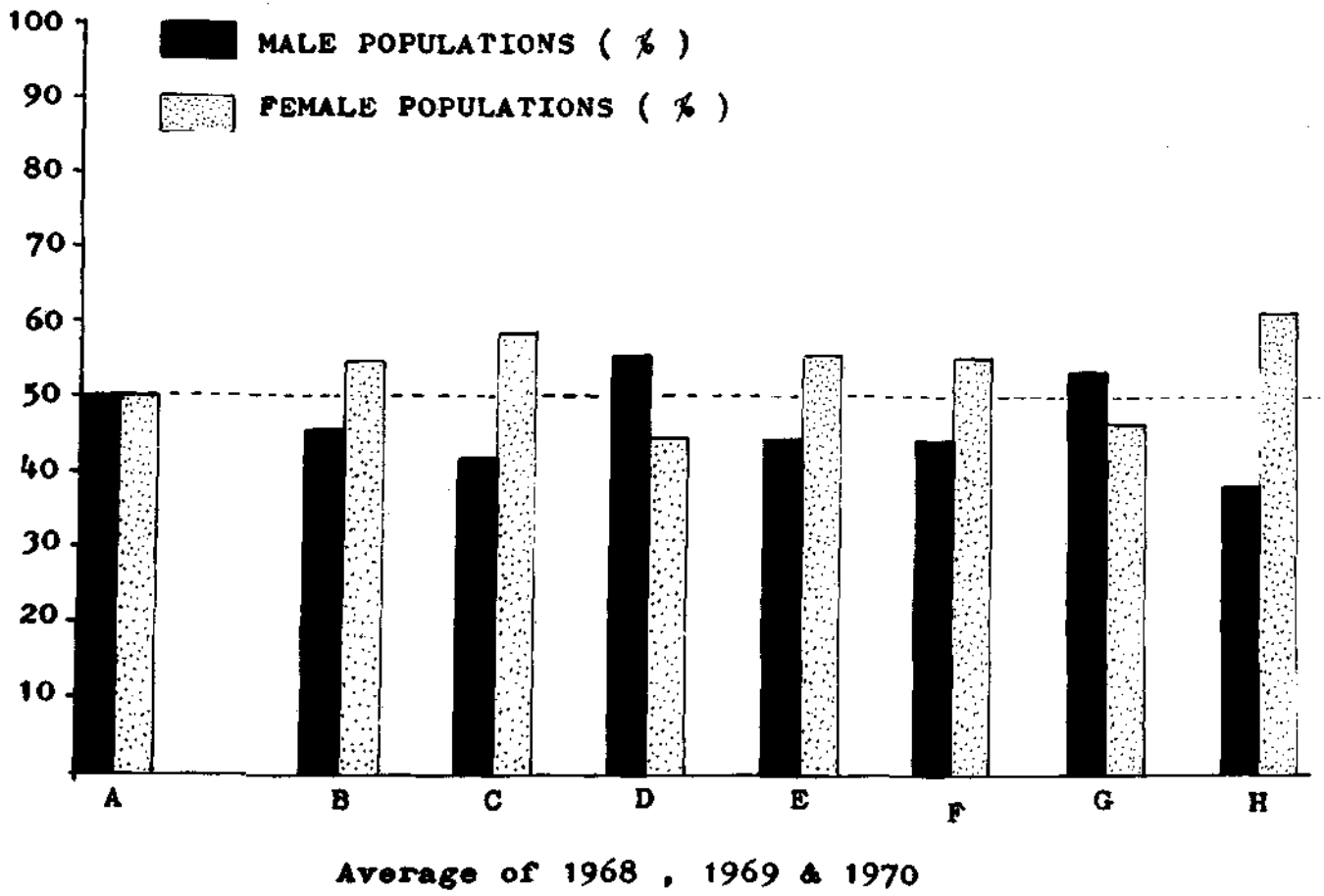

FIG.47: Histograms showing comparative catches of specimens of whole populations (B) and of Simulium (Eusimulium) praelargum n.sp.(C), S.(E.) gracilis n.sp. (D), Simulium (Simulium) himalayense Puri (E), Simulium (Gomphostilbia) tenuistylum n.sp.(F), S.(S.) grisescens Brunetti (G) and S.(S.) rufibasis Brunetti (H) of the present study in average of 1968, 1969 and 1970, in relation to the balanced state of sex-ratio (A)

Discussion

The observations made during the three years' period indicated that there were real differences in the sex-ratio among the species of black flies in Darjeeling if the method of light trapping could be relied upon for the purpose of such study. In the whole populations in each year the proportion of females was always higher than that of males and this tendency was found to maintain itself at all nights when the abundance of these insects was very low irrespective of species. The differing values of the whole populations for those years were evidently significant, except in 1968, when it was really insignificant. Williams (1964) also obtained significantly high numbers of females of black flies from a light trap in Scotland.

In the course of discussion on the results of the sex-ratios shown by the black flies taken in a light trap in Scotland, Davies and Williams (1962) held that the two sexes of different species of black flies might be differentially attracted to a light trap. In a similar way a specieswise estimation of the present investigation revealed that in himalayense the females consistently outnumbered males, and this was also the case in praelargum, except in 1968, when the proportion of males was much higher than that of females. Both rufibasis and tenuistylum showed an excess of females

over males in 1969 as well as in 1970. But in 1968 males of both the species exceeded females. Both in gracilis and grisescens the males predominated over females, except in 1968 when in both these two species females outnumbered males. The deviation from an indicated trend of sex-ratio of a given species in 1968 was noteworthy, and this deviation was thought to be due to the natural calamity of 1968 in the form of heavy rainfall and extensive land slides which disturbed the breeding sites of one or other or both sexes of black flies which flourished during the pre-autumnal period in the study site.

Fredeen (1961) working with different types of traps always obtained a significantly high number of females of Simulium arcticum Mall in each trial. Kettle (1955) observed the differences in the sex-ratios of the British Culicoides obtained through various means. Williams (1939) also showed that in tipulids the sex-ratio varied from species to species, and even the closely related species showed opposite results. To correlate the behaviour of these insects it may be stated that the differences were due to the differential sensivity of the sexes to factors such as weather conditions, involving the emergence of adults, and the death-rate of one sex, or the influence of factors governing the night activity of one sex that were largely independent of those affecting another sex.

Davies, D.M. (1950) and Davies, L. (1957) found that black flies ceased biting and oviposition with the onset of

darkness. There were, however, records of biting in darkness by black flies in Guatemala (Dalmat, 1955), in the high altitudes of Utah (Peterson, 1956) and in Sudan (Lewis, 1957). It is to be noted that at least a few species of black flies are found to bite at night in Darjeeling, if not all. Males of those species might outnumber females, if the latter are thought to travel to other parts in search of appropriate hosts. A parallel situation might exist with males, since male swarms of black flies are often said to occur at considerable distances from breeding sites (Davies & Williams, 1962) resulting in the alteration of incidence picture as revealed by light trap. Again, as Wolfe and Peterson (1959) experienced in Quebec, floods, logging and fire which frequently occur in or nearabout the natural habitats of black flies in Darjeeling, might affect one or the other sex of a species population causing an arbitrary and abrupt change in the incidence pattern of that sex of black flies. Thus, the sex-ratio of black flies taken in the light trap was really the outcome of the interplay of several factors of unknown nature which would require further investigation.

Summary

The present investigation deals with the sex-ratios of six species of black flies taken in a light trap in Darjeeling for three consequtive years 1968, 1969 and 1970. In the whole

populations of black flies in each year the proportion of females was always higher than that of males. In a species-wise estimation it was observed that in himalayense, the females consistently outnumbered the males, while in praelargum, rufibasis and tenuistylum, the females exceeded males in 1969, as well as in 1970; but in 1968, the males of these species showed an excess over females. Both in gracilis and grisescens the males outnumbered the females except in 1968, when the females of both these species outnumbered the corresponding males. The deviation from an indicated trend of sex-ratio of a given species is discussed in details in the light of several possible factors governing the same.

INTERNAL CONDITION OF TRAPPED FEMALES

Introduction

Females of almost all the species of black flies belonging to the family Simuliidae are blood-suckers, attacking mostly homoiothermous animals in order to gain energy for ovarian development and oviposition (Cameron, 1922; Wu, 1931; Rubtzov, 1936; Lewis, 1953; Davies and Peterson, 1956). These females are found in nature in different internal conditions. Taking advantage of their positively photophilic habit (Williams and Davies, 1957) the incidence of unfed, blood-fed and gravid females was studied by Davies and Williams (1962) in Scotland using the Rothamsted light trap (Williams, 1948). The purpose of this present work is to assess statistically the incidence of unfed, blood-fed and gravid females of black flies in Darjeeling by light-trapping.

Methods

Females of all the six species of black flies investigated here, namely, Simulium (Eusimulium) praelargum, n.sp., S.(E.) gracilis, n.sp., Simulium (Simulium) himalayense Puri (1932a), S.(S.) grisescens Brunetti (1911), S.(S.) rufibasis Brunetti (1911) and Simulium (Gomphostilbia) tenuistylum, n.sp.

were collected by continuous light-trapping between 7 P.M. and 5 A.M. at Darjeeling Government College campus in 1790 trap-hours of 179 nights, from April 1, 1968 to September 30, 1968; in 1800 trap-hours of 180 nights, from April 1, 1969 to September 30, 1969; and in 1810 trap-hours of 181 nights, from April 1, 1970 to September 30, 1970 with the help of a simple trap device described in the page no. 132.

After the assortment of females and males of a given species, females of different internal conditions were identified by means of a stereoscopic binocular microscope following the method of Davies and Williams (1962). The female specimens engorged with blood were recognizable by the black colour of the blood-mass which was visible through the transparent ventral wall of the abdomen. Specimens having swollen abdomen with yellowish or light brown colour due to mature eggs and with or without the remnant of blood in the gut were considered to be the gravid females, while others having normal abdominal texture and neither with blood nor with mature eggs were taken to be the non-replete females. The placement of the intermediate specimens were, however, not always perfect.

Observations

The proportion of non-replete, replete and gravid females of the six major species of black flies in the annual incidence and in average are shown in the tables XVIII-XXI.

Table-XVIII

Estimation of the trapped females of black flies in the different internal conditions during April 1 - September 30,1968

Female population	Unfed-fed-gravid ratio	X^2-value
Whole population	284 : 235 : 307	9.83 ***
praelargum	45 : 38 : 36	1.12 *
gracilis	28 : 18 : 26	2.33 *
himalayense	78 : 72 : 95	3.48 *
grisescens	61 : 45 : 66	3.17 *
rufibasis	44 : 31 : 55	7.02 **
tenuistylum	28 : 31 : 29	0.17 *

*** Significant at 5% as well as 1% level.

** Significant at 5% level but insignificant at 1% level.

* Insignificant at both the levels.

Table-XIX

Estimation of the trapped females of black flies in the different internal conditions during April 1 - September 30, 1969

Female population	Unfed-fed-gravid ratio	X^2-value
Whole population	240 : 247 : 241	0.11 *
paelargum	60 : 42 : 61	4.22 *
gracilis	37 : 19 : 20	8.09 **
himalayense	68 : 94 : 44	18.20 ***
grisescens	15 : 27 : 38	10.12 ***
rufibasis	37 : 24 : 44	5.89 *
tenuistylum	23 : 41 : 34	5.03 *

*** Significant at both the levels.

** Significant at 5% level but insignificant at 1% level.

* Insignificant at both the levels.

Table-XX

Estimation of the trapped females of black flies in the different internal conditions during April 1 - September 30, 1970

Female population	Unfed-fed-gravid ratio	X^2-value
Whole population	530 : 506 : 603	9.35 ***
praelargum	145 : 128 : 104	6.74 **
gracilis	62 : 43 : 55	3.47 *
himalayense	164 : 153 : 194	5.30 *
grisescens	16 : 42 : 48	16.39 ***
rufibasis	99 : 84 : 132	11.49 ***
tenuistylum	44 : 56 : 70	5.97 *

*** Significant at 5% level as well as at 1% level.

** Significant at 5% level but insignificant at 1% level.

* Insignificant at both the levels.

Table-XXI

Estimation of the trapped females of black flies in the different internal conditions during the whole study-period (in average)

Female population	Unfed-fed-gravid ratio	X^2-value
Whole population	351 : 329 : 384	4.31 *
praelargum	83 : 69 : 67	2.08 *
gracilis	42 : 27 : 34	3.29 *
himalayense	103 : 106 : 111	0.30 *
grisescens	31 : 38 : 51	5.15 *
rufibasis	60 : 46 : 77	7.90 **
tenuistylum	32 : 43 : 44	2.23 *

** Significant at 5% level but insignificant at 1% level.

* Insignificant at both the levels.

It was found that the proportion of the unfed females of the whole population was higher than that of the fed females, but lower than that of the gravid ones, except in 1969, when the proportion of the fed females was higher than both the unfed and gravid females; the gravid ones being slightly greater in proportion than the unfed ones.

The incidence shown by different species in different years was variable, but the frequency of a particular condition was not significantly low in each species. It was further observed that the feeding of all the species continued throughout all the seasons of the study period and that the decline started with the advent of the winter. Blood-fed females of a given species were captured in larger numbers when the catch was small. The cumulative percentage of the total catch of the females of all the species in different internal conditions for the year and the average showing the trend of incidence is given in Table XXII.

Table-XXII

Percentage compositions of unfed, blood-fed and gravid specimens in the total annual and in average incidence of females of black flies

Species	Unfed				Blood-fed				Gravid			
	1968	1969	1970	Average	1968	1969	1970	Average	1968	1969	1970	Average
praelargum	37.8	36.8	38.5	37.8	31.9	25.8	33.9	31.6	30.3	37.4	27.6	30.6
gracilis	38.9	48.7	38.7	40.8	25.0	25.0	26.9	26.2	36.1	26.3	34.4	33.0
himalayense	31.8	33.0	32.1	32.2	29.4	45.6	29.9	33.2	38.8	21.4	38.0	34.6
grisescens	35.4	18.7	15.1	25.8	26.2	33.8	39.6	31.7	38.4	47.5	45.3	42.5
rufibasis	33.9	35.2	31.4	32.8	23.8	22.9	26.7	25.1	42.3	41.9	41.9	42.1
tenuistylum	31.8	23.5	25.9	26.9	35.2	41.8	32.9	36.1	33.0	34.7	41.2	37.0

Discussion

The incidence of the females of black flies in different internal conditions was found to vary from time to time, from night to night, from month to month and even from year to year. Davies and Williams (1962) working in Scotland also observed this variation and held that females in different physiological conditions would react differently either to the stimulus of the light trap or to the meterological conditions that were likely to influence their incidence in a given night. Moreover, the variable nature of the incidence shown by the females in different internal conditions could be correlated to the heterogeneity of these insects.

Although the ratio among three groups, unfed, fed and gravid females, considering the whole population, showed a significant departure from the hypothesis 1:1:1, in 1968 and also in 1970, but it was not significantly different statistically from the hypothesis when the average over the whole study period was considered. So, leaving the cases of a particular year or years, for which a lot of studies would be required to reveal the essence of the incidence, the average over the whole study period was taken into account. In fact, for the whole population, as well as for the different species, with the only exception of <u>rufibasis</u>, which at 5% level showed a ratio significantly different from the hypothesis on the basis of

average over the entire study period, the hypothetical ratio 1:1:1 was tenable, that is,the females in different internal conditions, namely, blood-fed, unfed and gravid ones appeared at the light trap almost in equal proportions.

Summary

The trapped females of six species of black flies taken in a light trap in Darjeeling for three consecutive years 1968, 1969 and 1970 were broadly categorized into three groups, namely, unfed, blood-fed and gravid ones depending upon their internal conditions, in order to examine the essence of their incidence patterns through statistical procedure. It was observed that the hypothetical ratio of the groups was tenable for the whole population as well as for most of the species, considering the average over the entire study period. However, the departure from the hypothesis in a given species or in the whole population in a given year has been shown critically by statistical evaluation.

HOST PREFERENCE

Introduction

Both male and female black flies feed on the nectar of flowers mainly to provide energy for flight (Strong et al.,1934; Hocking, 1953) and the females of almost all species feed on the blood of most homoiothermous animals to provide energy for ovarian development and oviposition (Cameron, 1922; Wu, 1931; Rubtzov, 1936; Lewis, 1953 and Davies and Peterson, 1956). The information on the feeding by black flies on man and domestic animals are numerous, but that on birds and wild animals are rather meagre. The poikilothermous animals are rarely fed on by black flies. The feeding activities of black flies are, however, closely related to the four variables, namely, temperature, relative humidity, wind velocity and changing light intensity (Peterson and Wolfe, 1956).

For the identification of the host blood from biting flies the precipitin test was widely used as an entomological tool (Lloyd et al., 1924; Johnson and Rawson, 1927; Rice and Barber, 1935; Rempel et al., 1946; Riddell et al., 1947; and Schubert and Kelley, 1950) and this technique was employed also for the study of black flies by several workers (Downe, 1957;

Downe and Morrison, 1957 and Davies et al., 1962) in different countries. In India records of blood-sucking by black flies are scanty (Becher, 1884; Senior-White, 1922 and, Perti and Lopez, 1962). A preliminary work on the identification of blood meals of black flies was first undertaken by Das Gupta et al. (1969) in Darjeeling. In order to augment the knowledge on the host preference of the Indian Simuliidae this investigation was undertaken in Darjeeling with numbers of blood engorged specimens available from the light trap device.

Methods

The materials for the precipitin test were only the blood engorged live female specimens of black flies (Simuliidae; Diptera) consisting of the six major species, namely, Simulium (Eusimulium) praelargum, n.sp., S.(E.) gracilis, n.sp. Simulium (Simulium) himalayense Puri (1932a), S.(S.) grisescens Brunetti (1911), S.(S.) rufibasis Brunetti (1911) and Simulium (Gomphostilbia) tenuistylum, n.sp., out of the total collection made by continuous light-trapping between 7 P.M. and 5 A.M. at Darjeeling Government College campus in 1790 trap-hours of 179 nights from April 1, 1968 to September 30, 1968 with the help of a simple light trap device described in page no. 132.

The method adopted in this study for the preparation of blood smears was based on the essential principles of Eligh

(1952). The blood engorged specimens of a given species were pressed against heavily by means of the thumb and forefinger round the periphery of the filter paper and then the remnant of the insect body was wiped clean off the paper. The smears were then allowed to dry slowly within a dessicator to get satisfactory results (Boreham in personal communication, 1968).

Following the method of Weitz (1956) the blood smears were subjected to the precipitin test. Those smears were extracted in 1 c.c. of physiological saline (P^H 7) for a considerable period at room temperature. The extracts thus obtained were layered in 0.05 c.c. amounts over an equal volume of appropriate antiserum in small serological tubes which were kept under observations for precipitin rings. Both positive and negative controls were tried, wherever possible, for the series of tests.

The procedure adopted was to test first of all with general mammalian anti-serum and anything that did not react was tested against general avian and general reptilian antisera. Any positive mammal feed was tested for man, bovid, horse, pig, rodent and carnivore, and all positive bovid feeds for sheep/goat.

Observations

Out of 97 blood-meals 73 reacted with appropriate antisera in a positive way. The sources of blood-meals of the six major species of black flies are shown in the table XXIII.

Table-XXIII

Blood-meals of black flies reacted positively

Hosts	*praelargum*	*gracilis*	*himalayense*	*grisescens*	*rufibasis*	*tenuistylum*
Bird	-	-	4	-	-	-
Man	1	-	1	-	-	-
Carnivore	-	-	1	--	-	-
Rodent	-	-	-	1	-	-
Horse	-	-	3	-	1	1
Pig	-	-	3	-	-	-
Cow	-	-	18	9	4	3
Sheep/goat	-	-	1	1	-	-
Unidentified bovid*	1	-	2	2	3	-
Unidentified mammal**	1	1	4	4	3	-

* Weak feeds derived from the bovids and could include Sheep/goat.

** Weak feeds derived from the mammals and could include the species tested for.

The following is a specieswise description of host-preferences of the black flies of Darjeeling.

Simulium (Eusimulium) praelargum, n.sp.: This species was found to bite man in dull weather during collection in the field. In the precipitin test one blood-meal was found to have been taken from man. This species was also found to feed on some unidentified member of the bovidae and other mammalia.

Simulium (Eusimulium) gracilis, n.sp.: A single blood meal was found to have been taken from a mammal which could not be identified.

Simulium (Simulium) himalayense: The largest single group of blood-meals in this species was from the cow (18 out of 37). This species was also found to take its blood-meals from man, a carnivore, horse, pig, sheep or goat. It was also found to have fed on other bovids or some other mammals as shown by the test. However, an additional category of blood source for this species was from birds.

Simulium (Simulium) grisescens: This species was found to take its major blood-meals (over 50%) from the cow. It was found to feed on sheep or goat. It also fed on unidentified bovids or other mammals. This species also fed on an unidentified rodent.

Simulium (Simulium) rufibasis: This species fed predominantly on cows and also fed on the horse. It also fed on some other bovids excluding the cow, and also on some unidentified mammals.

Simulium (Gomphostilbia) tenuistylum, n.sp.: Only the cow and the horse were found to be the hosts of the species as revealed by the precipitin test; but this species is known to bite man in nature.

Discussion

In course of the present study himalayense was found to have a very wide range of hosts including birds and mammals. This species showed a preference for the cow, though other mammals including man, a carnivore, horse, pig, sheep or goat were also not spared. The carnivore could be a dog, a tiger, a leopard, a civet cat or a bear which occured in the Zoological Park beside the trapping site.

Shewell (1955) suggested the presence of the large basal tooth on the tarsal claw of several species to be an adaptation for feeding on birds. Four, out of the six species, namely, himalayense, praelargum, gracilis and tenuistylum actually possessed toothed tarsal claw. The former species having very small sub-basal tooth (Puri, 1932a) was found to have bird-feeding habit, but the latter three species having large basal tooth indicated no ornithophilic habit within this brief trial of the investigation. Hargreaves (1925), le Roux (1929), Fain (1950), and Fallis and Bennet (1958), as stated by Fallis (1964), however, noted exceptions to the rule among the Ethiopian black flies. S.(E.) praelargum, n.sp. and S.(S.)

himalayense fed on man while no other species did so. S.(G.) tenuistylum, n.sp. and S.(S.) rufibasis were found to feed on horse and cow. S.(S.) grisescens was unique in feeding on rodent which might be a flying squirrel or an unstriped squirrel occurring in the locality. This species as well as himalayense fed on sheep or goat. All of these species, excepting tenuistylum, fed on other unidentified mammals as indicated by the precipitin test. Moreover, there should be some composite blood-meals of black flies but those could not be differentiated in these studies. However, it might be noted, as pointed out by Bates (1949) and also by Glasgow et al. (1958), that the identification of simuliid blood-meals were often subject to a strong bias produced by several potential factors influencing these flies.

Studies were made in other countries on the feeding period of black flies (see Fallis, 1964). It was of interest to note that the fed flies entered the light trap throughout the dark period, as was also recorded by Davies and Williams (1962). Peterson (1956) also recorded feeding of some flies at night at high altitude in Utah. In Darjeeling more fed females were trapped at the beginning and at the end of the night when the incidence of these flies was much poorer than in the middle phase of the night.

Black flies were found to show their feeding activity during occasional drizzle with over 55%-95% of relative humidity.

Rubtzov (1939) found greatest activity to occur in 75%-90% relative humidity. Underhill (1940) observed feeding at the relative humidity as low as 42% with a peak between 65%-75%, but later he (Underhill, 1944) held that there was no definite relationship between relative humidity and blood-sucking and, observed that active feeding would occur between 52% and 94% relative humidity. According to Davies (1952) most flying activity occurred in moist air, i.e., at 70%-90% relative humidity but not when it was close to saturation point. Wolfe and Peterson (1960) noticed feeding of Simulium venustum say at 25%-95% relative humidity and a remarkable decline if it was raining. Anderson and de Foliart (1961), however, reported little effect of humidity on the ornithophilic species.

Temperature was important in influencing the activity of black flies. Activity was noted at temperatures of 10-30°C in Darjeeling. Rubtzov (1939) noted that the activity of black flies was normal at temperatures between 10-29°C with the optimum at about 20-23°C. Underhill (1939, 1940) observed more flies to feed between 24°C and 29.4°C, and few to feed below 21°C or above 32.2°C. According to Davies (1952) more flies were on the wing between 15.5°C and 26.6°C, with most possibly at 24°C-26.6°C. Dalmat (1954, 1955) from extensive studies of three species concluded that the optimum temperature for feeding of those species was about 34-35°C. Abreu (1960) recorded activity of Simulium damnosum Theobald at 27-30°C but not below 18°C or above 40°C.

Strong winds interrupted the activity and feeding as was also observed by several workers in different countries (Edwards, 1920; Edwards et al., 1939; Rubtzov, 1939; Underhill, 1940, 1944; Ogata, 1954; Davies, 1952; Peterson and Wolfe, 1956; Wolfe and Peterson, 1960; Anderson and de Foliart, 1961), and most active flying was found only when the air was calm or almost so as was remarked by Uvarov (1931).

The barometric change (Rubtzov, 1935; Underhill, 1939, 1940; Crisp, 1956), altitudinal effect (Strong et al., 1934; Fain, 1950; Dalmat, 1954, 1955; Peterson, 1956, 1959), and the physiological state of the individual fly (Rubtzov, 1951; Sailer, 1953; Davies, 1955, 1957 and Lewis, 1960 a, b) have a direct bearing on the activity of these insects. In fact, so far as the observations were concerned, the most active flying and feeding of black flies in Darjeeling were indicated during the period of occasional drizzle and in almost calm air accompanied by dull cloudy weather.

Summary

The present investigation deals with the host preferences of six species of black flies (Simuliidae) of Darjeeling from the blood-meal identification by precipitin test. S.(E.) praelargum, n.sp., sucks blood from man. S.(S.) himalayense Puri (1932a) has a very wide range of hosts from birds to mammals, the latter included man, a carnivore, horse, pig, cow and sheep or

goat. S.(S.) grisescens Brunetti (1911) feeds on a rodent, cow and sheep or goat. S.(S.) rufibasis Brunetti (1911) sucks blood from horse and cow. All these species show also to have fed on some other members of mammalia including other bovids. S.(E.) gracilis, n.sp., is the blood-sucker of a mammal other than the member mentioned above. S.(G.) tenuistylum, n.sp., feeds on horse and cow as shown by the test, but it also bites man in nature.

The feeding period of these flies continued throughout the night but more fed flies were trapped at the beginning and at the end than at the middle phase of the night. The most active feeding was enhanced by occasional drizzle and by almost calm air accompanied by dull cloudy weather which has been discussed in details.

NOCTURNAL PERIODICITY

Introduction

Black flies belonging to the family Simuliidae (Diptera) exhibit considerable night activity (Williams and Davies, 1957) and according to Williams (1964) their activities continue for a long period in the night. Rubtzov (1936) and Ussova (1961) on the other hand believed that daylight would be an essential factor for adult activity. Nocturnal activity of Tipulinae (Diptera) was earlier demonstrated by Pinchin and Anderson (1936) using a light trap, and similar work was reported on heleid midges (Diptera) by Sen and Das Gupta (1959). The present investigation was undertaken to find out the nocturnal activity of adult black flies in Darjeeling, a hilly area of the eastern Himalayas.

Methods

Specimens of black flies were collected by continuous trapping at Darjeeling Government College campus from 7 P.M. to 5 A.M. for a total of 45 hours between May 10, 1969 and August 28, 1969, with the help of a simple light trap device described in page no.132, and data were obtained to estimate the nocturnal periodicity of these species of insects. During

a particular night collection was made in three shifts, each of three-hours' duration. The first shift was between 7 P.M. and 10 P.M., the second shift between 10.30 P.M. and 1.30 A.M. and the third or the last shift between 2 A.M. and 5 A.M. A half-an-hour time period between the shifts was permitted for sorting out different species trapped in the previous shift.

Observations

All the major six species of black flies, namely, Simulium (Eusimulium) praelargum, n.sp., S.(E.) gracilis, n.sp., Simulium (Simulium) himalayense Puri (1932a), S.(S.) grisescens Brunetti (1911), S.(S.) rufibasis Brunetti (1911) and Simulium (Gomphostilbia) tenuistylum, n.sp., were studied and incidence of these flies is shown in the Table XXIV.

The incidence of black flies was marked by hourly variation and the peak (except for rufibasis) was attained during the middle of the night when the flies accounted for 60.9% of the total catch. The incidence was at its lowest during the first shift, with 17.2% of the total catch; while the third shift yielded 21.9% only.

In a species-wise estimation, praelargum showed a varying periodicity with the incidence in three shifts as 25%, 60.7% and 14.3% in succession, and this was unlike the general trend of the insect, but gracilis was found to maintain the

Table-XXIV

Prevalence of black flies at different hours of the night in Darjeeling

Date of collection	Species	Number of specimens in different shifts						Total
		Shift I		Shift II		Shift III		
		♀	♂	♀	♂	♀	♂	
10.5.69	*praelargum*	1	0	3	1	1	1	7
	gracilis	0	3	5	7	3	1	19
	himalayense	0	0	3	0	1	0	4
	grisescens	1	0	0	2	0	1	4
	rufibasis	0	0	0	0	0	0	0
	tenuistylum	0	0	1	0	1	0	2
21.5.69	*praelargum*	2	1	7	2	1	0	13
	gracilis	0	0	1	0	0	0	1
	himalayense	3	2	17	15	1	4	42
	grisescens	2	0	3	2	3	0	10
	rufibasis	1	0	0	0	0	0	1
	tenuistylum	1	0	1	0	0	0	2
2.6.69	*praelargum*	1	0	1	0	0	0	2
	gracilis	0	1	1	0	1	0	3
	himalayense	1	0	3	2	1	0	7
	grisescens	0	0	1	0	0	0	1
	rufibasis	1	0	1	0	0	1	3
	tenuistylum	3	1	7	12	1	1	25
24.6.69	*praelargum*	0	1	2	0	0	0	3
	gracilis	0	0	2	0	0	0	2
	himalayense	1	0	3	0	1	0	5
	grisescens	0	0	1	1	0	0	2
	rufibasis	2	1	4	2	9	6	24
	tenuistylum	0	0	0	0	1	0	1
28.8.69	*praelargum*	1	0	1	0	1	0	3
	gracilis	0	1	0	0	1	0	2
	himalayense	0	2	3	1	1	0	7
	grisescens	0	0	1	0	1	0	2
	rufibasis	0	0	0	1	0	0	1
	tenuistylum	0	2	5	3	1	1	12
TOTAL		21	15	77	51	30	16	210

general trend with the incidence during the three shifts as 18.5%, 59.3% and 22.2% in succession. The incidence patterns shown by himalayense during the three shifts were 13.8%, 72.4% and 13.8%, the sequence in the first shift and the last shift being equal, while grisescens obeyed the general trend of the insect with the incidence in three shifts as 15.8%, 57.9% and 26.3% in succession. S.(S.) rufibasis showed completely different periodicity in that the species was at its peak during the end of the night with the percentage of incidence as 17.2%, 27.6% and 55.2% in the three respective shifts. S.(G.) tenuistylum showed the trend of praelargum in periodicity with the sequence of incidence in three shifts as 16.6%, 69.1% and 14.3% respectively.

The two sexes of a species occasionally showed different periodicities. However, both the sexes of all the species excepting rufibasis were dominant during the middle of the night. S.(S.) rufibasis was, in fact, dominant in the last part of the night with the percentage distribution at 22.3%, 27.7% and 50% in females, and at 9%, 27.3% and 63.7% in males. Only in the females of grisescens the incidence assumed the general trend of the insect on the whole with 23.1%, 46.2% and 30.7% of the total catch of the sex, while the males of the species were unrepresented in the first shift of the night and accordingly the percentage compositions of the middle and

the last shifts were 83.3% and 16.7% respectively for males. The females of gracilis were also unrepresented in the first part of the night and the incidences of the second and the third shifts of the night were 64.3% and 35.7% respectively, for females, while in males the incidence was 38.5%, 54% and 7.5% in succession, the lowest being registered in the last shift of the night. Both the females and males of praelargum and the males of tenuistylum showed an incidence pattern similar to that shown by the males of gracilis. The percentage distributions in three shifts of the night in succession were at 22.8%, 63.6% and 13.6% for the females of praelargum, at 33.3%, 50% and 16.7% for the males of praelargum and at 15%, 75% and 10% for the males of tenuistylum respectively. In the females of tenuistylum, however, the incidence was equal in the first shift and in the last shift of the night and comprised of 18.2% in both the cases and there was a peak with 63.6% during the middle shift of the night. Both males and females of himalayense showed the above trend with the percentage distribution at 15.4% in both the first and the last shifts and 69.2% in the middle of the night for the former, and at 12.8% in both the first and the last shifts and 74.4% in the middle of the night for the latter, respectively.

The Chi-square analyses of the 19-patterns of nocturnal periodicity encountered involving the six species of black flies are shown in the Table XXV.

Table-XXV

Chi-square analyses of the incidence frequencies of black flies at different parts of night (based on Table XXIV)

Types of incidence	Frequency in three shifts			Chi-square value
1. Total population of six species	36	128	46	55.06 ***
2. *praelargum*-population	7	17	4	9.96 ***
3. *gracilis*-population	5	16	6	8.22 **
4. *himalayense*-population	9	47	9	44.35 ***
5. *grisescens*-population	3	11	5	5.50 *
6. *rufibasis*-population	5	8	16	6.66 **
7. *tenuistylum*-population	7	29	6	24.14 ***
8. Female-populations	21	77	30	42.37 ***
9. Male-populations	15	51	16	30.88 ***
10. *praelargum*-females	5	14	3	9.40 ***
11. *himalayense*-females	5	29	5	29.53 ***
12. *grisescens*-females	3	6	4	1.08 *
13. *rufibasis*-females	4	5	9	2.33 *
14. *tenuistylum*-females	4	14	4	9.13 **
15. *praelargum*-males	2	3	1	1.00 *
16. *gracilis*-males	5	7	1	4.34 *
17. *himalayense*-males	4	18	4	15.02 ***
18. *rufibasis*-males	1	3	7	5.04 *
19. *tenuistylum*-males	3	15	2	15.62 ***

*** Significant at 5% as well as 1% level.

** Significant at 5% level but insignificant at 1% level.

* Insignificant at both the levels.

Discussion

Observations on the nocturnal periodicity of the six species of black flies revealed that there was a significant difference in the activities of these insects at different hours of the night and all of them with the exception of rufibasis showed the highest incidence in the middle of night, i.e., between 10.30 P.M. and 1.30 A.M. However, rufibasis showed its peak abundance during the last part of the night, i.e., between 2 A.M. and 5 A.M. Minář (1962), working with five species of Simuliidae, observed that black flies showed their maximum activity at 6 A.M. and upto 6 to 7 P.M. but the activity ceased in the middle of the day. In Kenya, McMahon (1947) noted that Simulium neavei Roubaud showed its maximum activity from 9 A.M. to 11.30 A.M. and from 3 P.M. to 6.30 P.M. According to Wolfe and Peterson (1960) black flies were most active in the morning, one to two hours after dawn, and in the evening, half-an-hour to one hour before sun-set, and at night they moved to resting places in the tops of the trees, probably because of the more suitable light intensity at higher levels just before darkness. Peterson (1956) recorded activity of some species at night in Utah at high altitudes. Bennet (1960) recorded more flies from woodland birds late in the evening. In the Palaearctic region, Helodon ferrugineus Wahlberg was caught in the light trap during night by Kureck (1969). Thus, the activities of black flies are not restricted in day time only. Williams (1964)

experimentally proved that the activity of these insects continued throughout the night and that the activity became dominant during the middle of the night, when conditions were favourable. These suggestions made by him confirm the results of this investigation. In a similar type of experiments with Tipulinae Pinchin and Anderson (1936) observed that these insects showed the maximum activity at dusk and, Sen and Das Gupta (1959) found that the heleid midges were most active in the early hours of the night and according to them different periodicities might be shown by the two sexes of a given species.

In the present investigation both sexes of all the species showed the peak abundance as represented for the given species in the same time-period, but no distinctive conclusion could be made from these brief trapping data as to whether the two sexes of a species would show different periodicities, as was shown by Pinchin and Anderson (1936) in the case of Tipulinae in which females were on the wing at dusk while the males appeared an hour later. The present investigation, however, indicated that the percentage distribution of the females of a given species in every shift was significantly higher than that of the males of the same species and this was true for most of the species, as was shown earlier by Williams (1964) in Scotland. However, the two sexes of a species might respond to the different hours of the night differently even in the favourable meteorological conditions for both of the sexes of black flies.

Summary

The nocturnal periodicity of six species of black flies of Darjeeling was found out from the data of light-trapping made in three equal shifts for each of the five nights selected in 1969. The incidence of these flies was marked by hourly variation. Each of S.(E.) praelargum, n.sp., S.(E.) gracilis, n.sp., S.(S.) himalayense Puri (1932), S.(S.) grisescens Brunetti (1911) and S.(G.) tenuistylum, n.sp., showed its peak abundance in the middle of night, while S.(S.) rufibasis Brunetti (1911) was at its peak at the end of the night. The percentage composition of gracilis and grisescens in the last shift was higher than that in the first shift, and this was the general trend of the species of these flies taken together. The incidence of praelargum and tenuistylum in the first shift was higher than that in the last shift. In himalayense the distribution was similar in any of the two shifts, while in rufibasis it was found to rise gradually, thereby attaining itself to its peak at the end of the night. The incidence shown by the two sexes of a species did not always obey the general trend and this is discussed in details.

PHOTOPHILIC BEHAVIOUR

Introduction

Black flies belonging to the family Simuliidae (Diptera) are known to be positively phototropic insects (Williams and Davies, 1957). Kohler and Fox (1951) performed an experiment on the Puerto Rican Culicoides (Ceratopogonidae) by means of the New Jersey light trap (Headlee, 1932) using chrome yellow and green lights to ascertain the relative attractiveness of the insects to these colours. Observations on the landing of black flies depending on the colour of their hosts were also recorded by Davies (1951, 1961) and Vargas (1945). A study was undertaken to find out the photophilic behaviour of black flies of Darjeeling using some desirable coloured lights.

Methods

A Chinsura light trap (Banerjee and Basu, 1956) was operated simultaneously for the control experiment beside the regular light trap device (see page no.132) meant for the treated experiments. A 200 wattage lamp was used as the light source of each of the trap which were made operational by turning on its light source daily at 7 P.M., and the trapping continued till

5 A.M. of the following day. The experiment was conducted at Darjeeling Government College campus for 68 nights during the months of March and October of 1968, 1969 and 1970. The light source of the treated trap was wrapped around by a transparent cellophane paper of a desirable colour, while that of the control trap was white as usual for all the series of performance. The incidence of black flies taken in the treated series was compared with that of the control ones in order to find out the colour preference of these insects.

Observations

Black flies collected by the above method were found to consist of the six major species, namely, Simulium (Eusimulium) praelargum, n.sp., S.(E.) gracilis, n.sp., Simulium (Simulium) himalayense Puri (1932a), S.(S.) grisescens Brunetti (1911), S.(S.) rufibasis Brunetti (1911) and Simulium (Gomphostilbia) tenuistylum, n.sp. The incidence of these flies in the traps are shown in the following Tables XXVI-XXX.

Table-XXVI

Black flies taken in the treated trap with chrome yellow light source as against the control trap tested for 14 days

Species	Number of specimens taken in light trap		Percentage of incidence in Chrome yellow light
	Control	Treated	
praelargum	14	12	46.1
gracilis	10	11	52.4
himalayense	20	16	44.4
grisescens	7	4	36.4
rufibasis	13	12	48.0
tenuistylum	5	5	50.0

The incidence of black flies in the control trap was slightly greater than that of the treated trap excepting in the case of *gracilis* and *tenuistylum*. The former species taken in the treated trap showed a slightly higher proportion of incidence, while the latter occurred in equal proportions in both the traps.

Table-XXVII

Black flies taken in the treated trap with dark red light source as against the control trap tested for 17 days

Species	Number of specimens taken in light trap		Percentage of incidence in dark red light
	Control	Treated	
praelargum	20	15	42.9
gracilis	12	9	42.9
himalayense	22	17	41.0
grisescens	10	7	41.2
rufibasis	11	9	45.0
tenuistylum	4	2	33.3

The incidence of all the black flies taken in the treated trap using dark red light source was always lower (much below 50%) than that taken in the control trap. *S.(G.) tenuistylum*, n.sp., however, showed the incidence only above 30% level.

Table-XXVIII

Black flies taken in the treated trap with forest green light source as against the control trap tested for 15 days

Species	Number of specimens taken in light trap		Percentage of incidence in forest green light
	Control	Treated	
praelargum	20	7	26.0
gracilis	14	6	30.0
himalayense	31	14	31.1
grisescens	15	7	31.8
rufibasis	18	8	30.8
tenuistylum	7	2	22.2

The incidence of black flies excepting *praelargum* and *tenuistylum*, taken in the treated trap with forest green light source was found to be 30% or just above 30% level, while *praelargum* and *tenuistylum* showed lower percentage of incidence below 30% level. In all cases, however, the appearance of females in the treated trap was scarce.

Table-XXIX

Black flies taken in the treated trap with dark blue light source as against the control trap tested for 12 days

Species	Number of specimens taken in light trap		Percentage of incidence in dark blue light
	Control	Treated	
praelargum	17	7	29.2
gracilis	11	2	15.4
himalayense	24	9	27.3
grisescens	15	5	25.0
rufibasis	18	6	25.0
tenuistylum	7	1	12.0

The incidence of black flies taken in the treated trap using dark blue lamp as the light source was very poor. The two species *gracilis* and *tenuistylum* showed the incidence at 15.4% and 12.5% level respectively, while the others registered this incidence between 25% and 30% level. The most important feature of this experiment was that the treated trap captured only the female specimens instead of admixture of both the sexes as evidenced in other experiments.

Table-XXX

Black flies taken in the treated trap with snow white light source as against the control trap tested for 10 days

Species	Number of specimens taken in light trap		Percentage of incidence in snow white light
	Control	Treated	
praelargum	12	17	58.6
gracilis	8	14	63.6
himalayense	27	34	55.7
grisescens	9	12	57.1
rufibasis	15	16	51.6
tenuistylum	6	7	53.8

The picture of incidence of black flies taken in the trap with snow white light source was quite different in that all the species showed higher incidence in the treated trap than in the control one and the percentage of females captured was always above 50.

The incidence percentage for all the species of black flies taken in the treated series of experiments tried for five desirable colours with which the relative attractiveness of these insects was tested is shown in the following table (Table XXXI).

Table-XXXI

Incidence-percentage of black flies taken in the treated trap tried for 5-coloured light sources in 68 nights

Species	Chrome yellow	Dark red	Forest green	Dark blue	Snow white
praelargum	46.1	42.9	26.0	29.2	58.6
gracilis	52.4	42.9	30.0	15.4	63.6
himalayense	44.4	41.0	31.1	27.3	55.7
grisescens	36.4	41.2	31.8	25.0	57.1
rufibasis	48.0	45.0	30.8	25.0	51.6
tenuistylum	50.0	33.3	22.2	12.5	53.8

Discussion

The photophilic behaviour of the species of black flies in Darjeeling was very interesting as evidenced from the series of experiments with light traps, in which, as it was revealed, black flies were more attracted to snow white light than any other coloured light and the ordinary white light. The incidence percentage of a given species varied from colour to colour and the sequence of attractiveness for all but praelargum followed in this way: snow white, chrome yellow, dark red, forest green and dark blue. Only praelargum was least attracted to forest green light. The incidence of tenuistylum was obtained in equal proportions taken in the control and the treated traps with

chrome yellow light source, probably because of the scanty populations of the species, and this sort of variation in incidence was also shown by Kohler and Fox (1951) who experimented with Culicoides in Puerto Rico and demonstrated that the yellow trap made consistently higher catches than the forest green one, if the populations were not extremely low.

The reason of decreasing incidence with the declining sequence of attractiveness of black flies might be correlated with the limited dispersion of light rays from the coloured envelope of the treated trap which could be restricted beyond the span of these insects' activity in nature, if not to speak of their natural sensivity to different chromatic lights.

Moreover, two sexes of a species behaved in an opposite way. Thus, as the incidence of a species began to decline with the above trend of attractiveness, more and more female specimens were to appear in the treated trap excepting in the case of green light. According to Davies and Williams (1962) two sexes of a given species or two species of a given population of black flies might be attracted to light differentially. The results of the present investigation confirmed this view. Davies (1951, 1961) held that females of Simulium venustum Say were attracted more to dark blue cloth than to other coloured cloth. It might be possible that females of a species would be influenced by the

excitement to one colour and not to another, which might be preferable to the other sex, depending upon the criteria of wavelength, intensity and purity of the colour chosen.

Summary

The photophilic behaviour of the six species of black flies (Simuliidae:Diptera) of Darjeeling, namely, Simulium (Eusimulium) praelargum, n.sp., S.(E.) gracilis, n.sp., Simulium (Simulium) himalayense Puri (1932), S.(S.) grisescens Brunetti (1911), S.(S.) rufibasis Brunetti (1911) and Simulium (Gomphostilbia) tenuistylum, n.sp., was tested with five different coloured lights. Black flies were more attracted to snow white light than by any other coloured light. The incidence percentage of a given species varied from colour to colour, and the sequence of attractiveness for all but praelargum followed in this way: snow white, chrome yellow, dark red, forest green and dark blue. Only praelargum was least attracted to forest green light. The relative attractiveness of both sexes differed to a considerable extent. The reason of decreasing incidence with the declining sequence of attractiveness of black flies is discussed.