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ENVIRONMENTAL FACTORS AND REPRODUCTIVE SEASONALITY IN THE INDIAN LANGUR, *PRESBYTIS ENTELLUS*, ON THE INDIAN SUBCONTINENT

By

P. L. KANKANE

Zoological Survey of India, Calcutta

INTRODUCTION

Mammalian and avian reproductive cycles are the result of interaction between endogenous and exogenous factors. It has been demonstrated repeatedly that endogenous factors alone cannot maintain a regular periodicity of birth seasons indefinitely but must be triggered

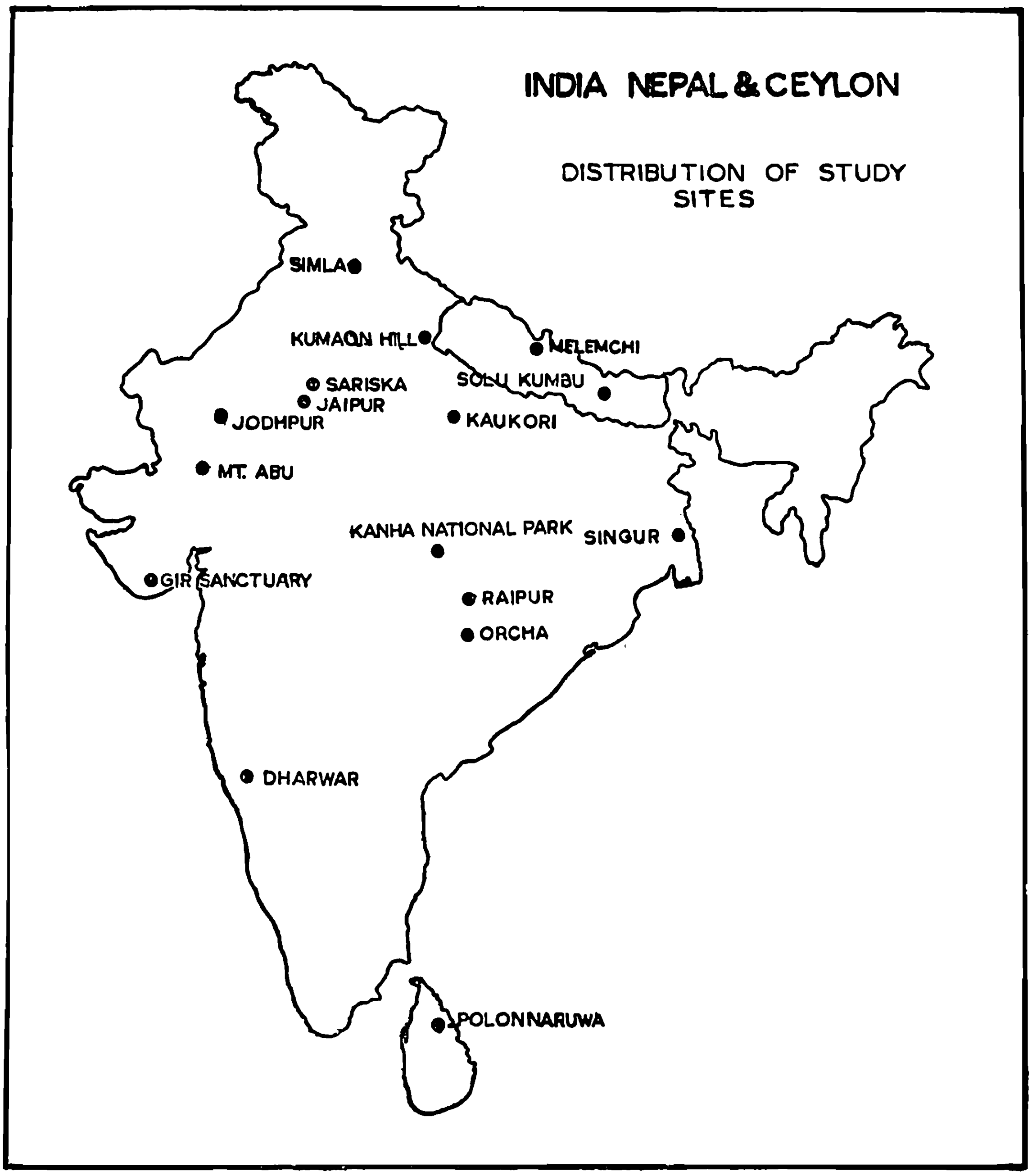


Fig. 1. Map of India, Nepal and Ceylon showing distribution of study sites.

and synchronized by stimuli external to the animal (Vandenbergh and Drickamer, 1974). These external stimuli are apparently combinations of climatological variables such as sunlight or ultraviolet light, relative humidity, temperature, rainfall and other factors that exhibit a seasonal rhythm and may mediate interindividual response. There appear to be three reproductive patterns among primates : truly seasonal breeders (e. g., *Macaca mulatta* ; Lindberg, 1971), mating throughout the year with a peak in breeding activities (e.g., *Presbytis entellus*, Dolhinow, 1972 ; Boggess, 1980 ; *Papio anubis*, Devore and Hall, 1965), and lack of an apparent peak period (e.g., *Papio ursinus*, Devore and Hall, 1965, *Pan troglodytes*, Wrangham, 1977).

TABLE 1. The Latitudinal, Longitudinal And Altitudinal Differences Between Weather Stations And Actual Study Area.

Sl. No.	Locality/(Weather Stations)	Latitude	Longitude	Altitude (m)
1.	Simla	31°06′N	77°10′E	1500-3200
2.	Kumaun Hills			900-1500
	(Nanital)	29°22′N	79°30′E	1953
3.	Solu Khumbu, E. Nepal	27°45′N	86°30′E	2433-3505
	(Thyangboche)	27°50′N	86°45′E	4000
4.	Jaipur	26°55′N	75°53′E	
5.	Sariska	21°12′N	77°20′E	400
	(Jaipur)	26°49′N	75°48′E	
6.	Kaukori	26°50′N	80°45′E	122
	(Lucknow)	26°55′N	80°59′E	122
7.	Jodhpur	26°18′N	73°04′E	241
8.	Mt Abu	24°40′N	72°45′E	1300
9.	Singur	22°45′N	88°10′E	7
	(Bagati)	22°59′N	88°22′E	
10.	Kanha National Park	22°15′N	80°35′E	
	(Mandla)	22°35′N	80°58′E	
11.	Raipur	21°15′N	81°41′E	290
12.	Gir Sanctuary	21°00′N	71°00′E	226-648
	(Veraval)	20°53′N	70°26′E	
13.	Orcha	19°10′N	81°30′E	762
	(Kanker)	20°15′N	81°32′E	
14.	Dharwar	15°27′N	75°05′E	550-760
	(Gadag)	15°25′N	75°42′E	
15.	Polonnaruwa	07°56′N	81°02′E	
	(Batticaloa)	07°43′N	81°42′E	

Places in parenthesis are weather stations.

The primary purpose of this paper is to correlate meteorological data for different langur study sites throughout the Indian subcontinent (Fig. 1) with reported mating and birth peaks (Table 1). Association between perodicity of flowering, and production of young leaves and langur reproductive patterns is also examined.

METHODS

The environmental factors considered for correlation with reproductive events are rainfall, maximum and minimum temperatures, morning and evening relative humidities, daylight hours, and numerical abundance of different phenological stages of plants on which langurs feed. The climatological data were obtained from weather stations of various Government Meterological departments located in or close to each study area. The daylight hours (in minutes) for study area are calculated on the basis of their longitude, adopting standard procedure. The climatological data (temperature, humidity and rainfall) were collected for the duration of the study period reported by different authors (Table 2). Each variable was then calculated in terms of "monthly avarage" and plotted on the graphs (Fig. 2) for each locality along with birth and mating peaks. It is the trend and not the exact temperature, humidity, rainfall which was correlated with reproductive events.

The availability of preferred food in different months is presented in Table 3, listing localities for which the number of food plants and their phenological cycles are available. Different phenological periods such as flowering, and production of young leaves were plotted by locality according to season of availability based on published records. The number of plant parts from all plant species available to langur populations during each month is indicated in Table 3. For example, number 12 in January at Dharwar indicates that langurs had twelve different phytophases of the total of thirty-seven plants species at their disposal. Because the relative densities of the plant species utilized by langurs are not known for sites other than Dharwar, Table 3 indicates comparative abundance of fruits, leaves and flowers over the year.

The data on population and breeding activities of *Presbytis entellus* were taken from published works from thirteen different locations through out India, Nepal and Sri Lanka, including six of the fifteen subspecies of *P. entellus* (Table 2).

TABLE 2. Summary of the work Done on the Hanuman Langur, *Presbytis entellus* in different localities.

Sl. No.	Localities	Investigator	Period of Study	Subspecies	Habitat	Kind of Group	Density Heads/ km²	Average Group Size	Home Range km²/ Group	Adult Male/ Adult Female	Infant/ Adult Female	References
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Simla	Sugiyama,	Aug. 72-Jan. 73	*schistaceus*	Himalayan moist temperate forest	Onemale Multimale All-male	24.6	46.8	1.9	0.27	0.42	Sugiyama, 1976
2.	Kumaon Hills	Vogel, C.	Sept. 68-Nov. 68	*entellus*	High altitude mountain forest	(Onemale) (Multimale) All-male	97.0	23.0 10.0	0.2	0.2	0.22	Vogel, 1971 Vogel, 1977
3.	Melemchi	Bishop, N.H.	Nov. 71-Sep. 72	*schistaceus*	Himalayan temperate forest	Multimale All-male	15.2	32.0	2.1	(0.77)	(0.75)	Bishop, 1979 Vogel, 1977
4.	Solu Kumbu	Curtin, R.A.	Oct. 72-Feb. 74	*achilles*	Coniferous & mixed broad leave forest	Onemale Multimale	(1.1)	11.0	(7.76)	(0.56)	—	Curtin 1975
5.	Jaipur	Prakash, I.	Feb. 56-Oct. 60	*entellus*	City & semiarid	Onemale (All-male)	—	15.0	—	0.06	—	Prakash, 1962
6.	Sariska	Vogel, C.	Sep. 68-Nov. 68	*entellus*	Dry scrub	Onemale (Multimale) All-male	104.0	64.0 21.0	6.0	0.38	—	Vogel, 1971 Vogel, 1977
7.	Kaukori	Jay, P.	Dec. 59-Mar. 60	*schistaceus*	Cultivated field	field Multimale All-male	2.6	54.0	7.76	0.31	0.74	Dolhinow, 1972

TABLE 2. (*Concluded*)

1	2	3	4	5	6	7	8	9	10	11	12	13
8.	Jodhpur	Mohnot, S.M.	Jul. 67-Aug. 68	*entellus*	Open scrub	Onemale All-male	19.0	18.0	0.5	0.04	—	Mohnot, 1971 Vogel, 1977
9.	Mt Abu	Hrdy, S.B.	Jun. 71-Oct. 75	*entellus*	Dry scrub	Onemale Multimale	50.2	24.0	0.38	0.18	0.70	Hrdy, 1974
10.	Singur	Oppenheimer, J. R.	Jan. 71-Aug. 72	*entellus*	Village	Onemale	4.6	12.8	0.43	0.18	0.5	Oppenheimer, 1977
11.	Kanha National Park	Kankane, P.L.	Mar. 77-Apr. 77	*entellus*	Dry & moist deciduous	Onemale Multimale	—	17.4	0.7	0.15	0.32	Kankane, 1980
12.	Raipur	Jay, P. Sugiyama, Y.	Nov. 62-	*entellus*	Dry & old scrub	Onemale Multimale	—	29.1	—	0.81	0.31	Jay, 1965 Sugiyama, 1976
13.	Gir Sanctuary	Rahaman, H.	Jul. 71-Aug. 71	*entellus*	Riverine & deciduous trees	Onemale Multimale All-male	—	(30.4)	(3.25)	(0.19)	(0.29)	Rahaman, 1973 Vogel, 1977
14.	Orcha	Jay, P.	Nov. 58-Nov. 59	*anchises*	Moist deciduous	Onemale Multimale All-male	(2.7-6.2)	22.0	3.88	0.17	—	Dolhinow, 1972
15.	Dharwar	Sugiyama, Y.	Apr. 61-Apr. 63	*achates*	Dry deciduous	Onemale All-male	16.6	17.1	1.5	0.16	0.24-0.3	Sugiyama, 1965 Sugiyama, 1975
16.	Polonnaruwa	Ripley, S.	Oct. 62-May 63	*thersites*	Dry deciduous	Multimale	58.0	25.0	0.43	—	—	Vogel, 1977 Ripley, 1967

(   ) Estimated or calculated by the present author.

TABLE 3. Comparative Availability of Different Phenological Stages of Prefered Food In Different Months.

Locality	Total No. of Plants Reported	Total No. of Plants Cited	J	F	M	A	M	J	J	A	S	O	N	D	References
Simla	26	21	0	4	10	12	12	8	2	4	4*	4*	2*	0	Collett, 1971
Jodhpur	53	52	17	17	16	16	13	13	14	29	39*	43*	37*	30*	Bhandari, 1978
Dharwar	39	37	12	9	7	10	27*	23*	19*	17*	18*	19*	8	9	Yoshiba, 1967
Singur	22	11	3	2	6	7	11	8	3	3	3	2	2	4	Bennet, 1979

*Mating peak reported during these months.

Presbytis entellus—An Overview

The whole of the northern peninsula is hot throughout the year except in the hills, and the wettest period extends from July to October. Though the rainfall pattern is maintained through intermonsoonal convectional currents, the effect of the dry season becomes pronounced as temperature rise, reaching a peak before the start of the yearly monsoon. With the arrival of the monsoon the temperature starts decreasing and continues to do so for the next two to three months.

On the Indian subcontinent langur populations live in a wide range of geographic and climatic variations. The study areas (Fig. 1) fall between 07°56'N to 31°06'N latitude and 70°00'E to 88°10'E longitudes, while the elevation varies from 7 m to 3505 m (though Bishop, 1977, has reported its occurrence at 4250 m at Routang in Nepal) above mean sea level. The temperature of their habitat ranges from subzero (−13°) to as high as 41°C, the relative humidity from 12% to 91% and the total annual precipitation from 408 mm to 1940 mm. There is a difference of nearly 24 degrees latitude between the northernmost populations of the Himalayan region (Simla) and the southernmost populations in Sri Lanka (Polonnaruwa). The maximum variation in the daylight hours between Simla and Polonnaruwa is 93 minutes in the month of January while the minimum is seven minutas in May. The overall difference irrespective of any month is 146 minutes. Simla experiences the highest variation in daylight hours which is 843 minutes (maximum) in July and 608 minutes (minimum) in January, a difference of 235 minutes. The climatic variables shown in Table 4 reveal the conditions prevailing in the beginning and at the end of the mating peak.

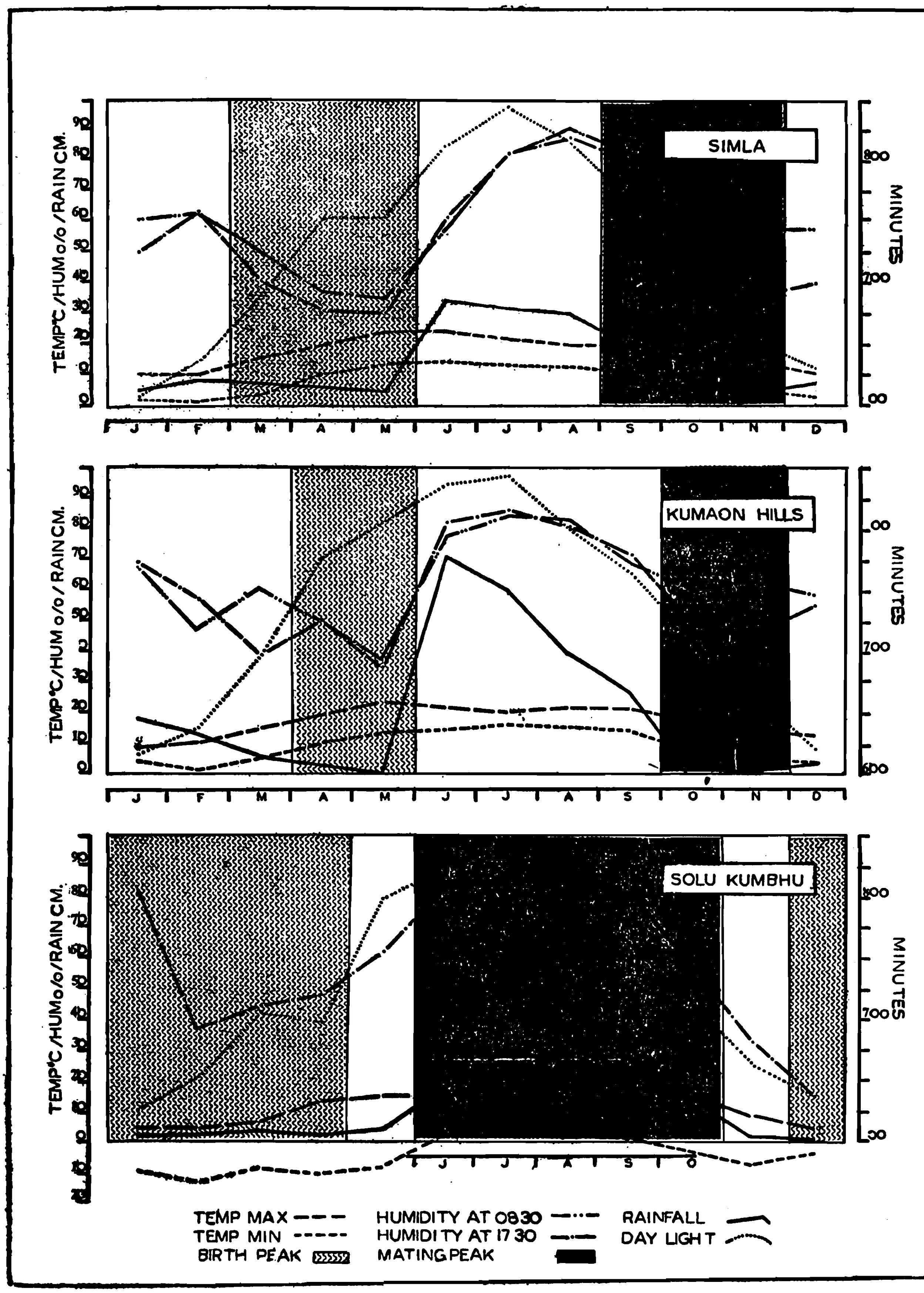
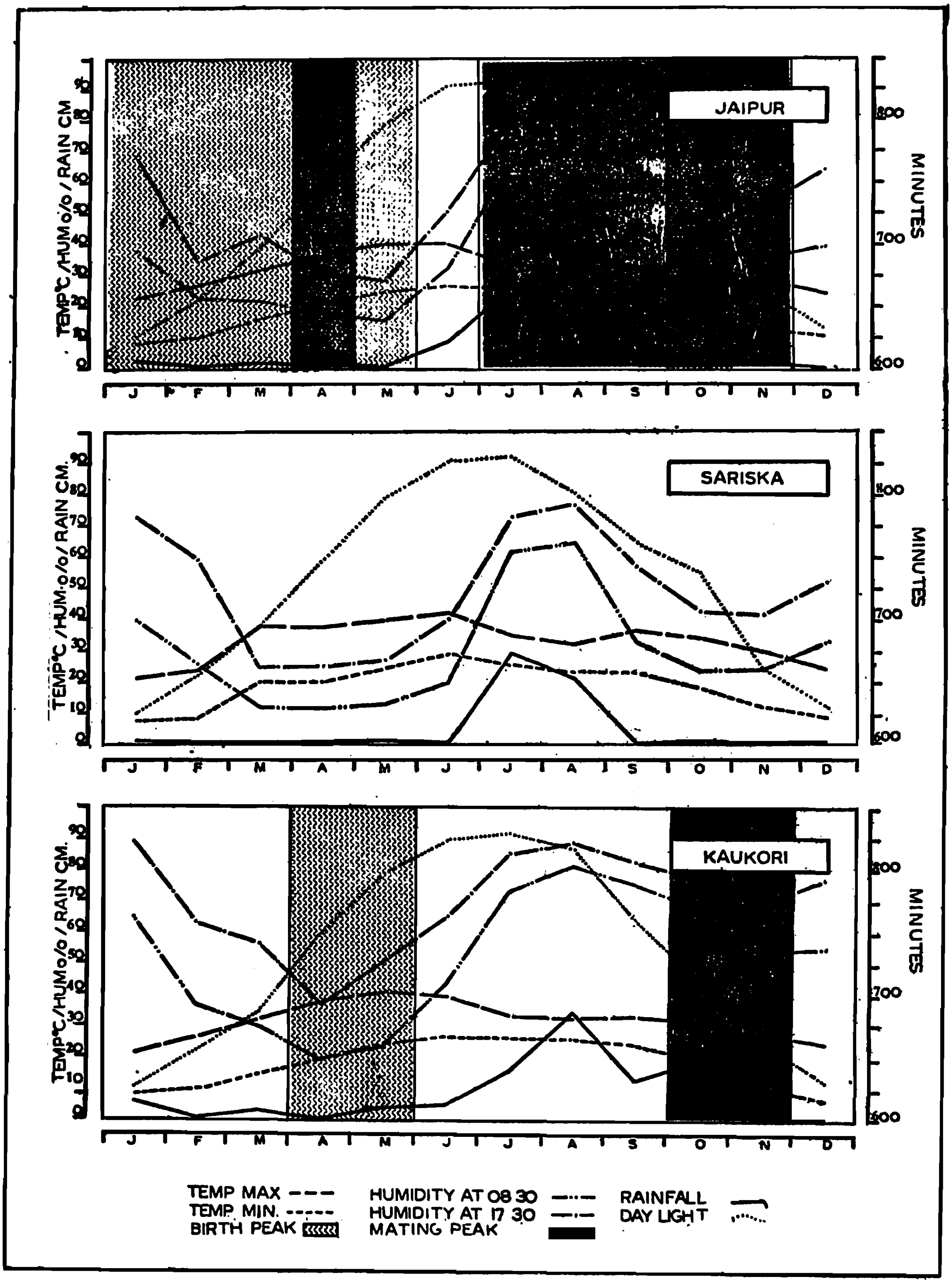


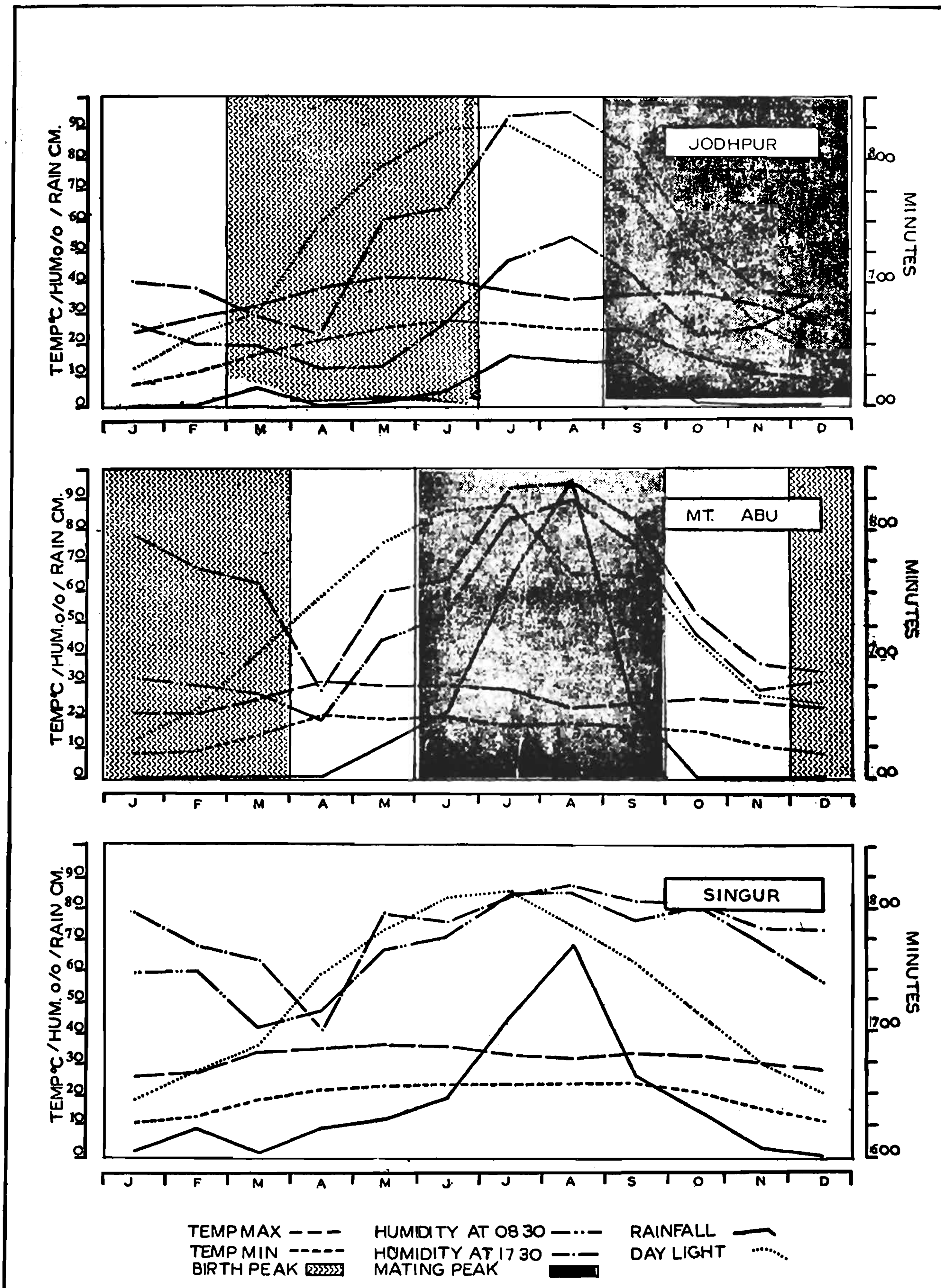
Fig. 2. The mating and birth peaks in the reproductive cycles of langurs in relation to average monthly maximum and minimum temperature morning and evening relative humidity, rainfall and daylight hours.

(in five sheets)

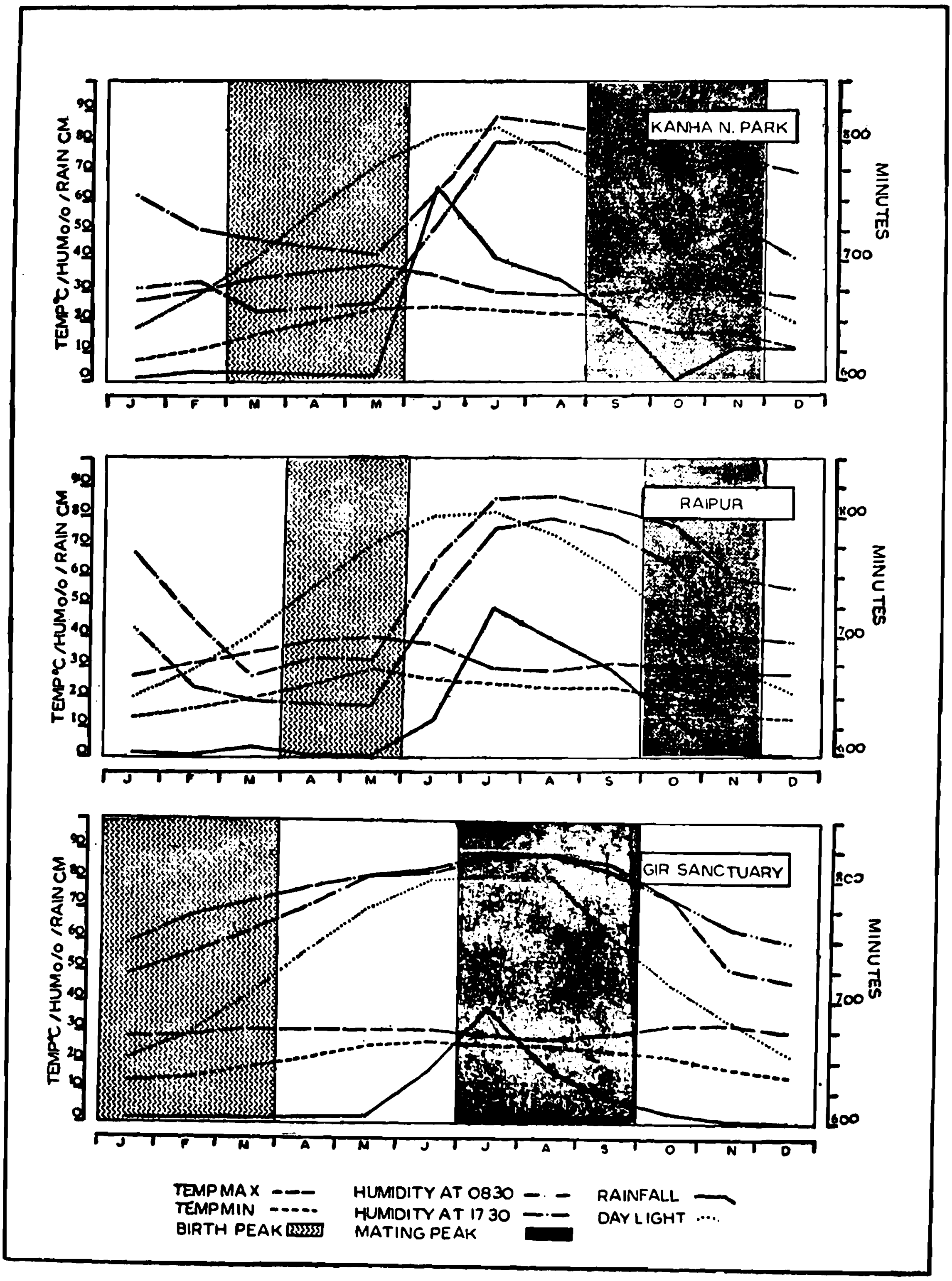
Sheet 1 depicts Simla, Kumaun Hills Solu Kumbhu



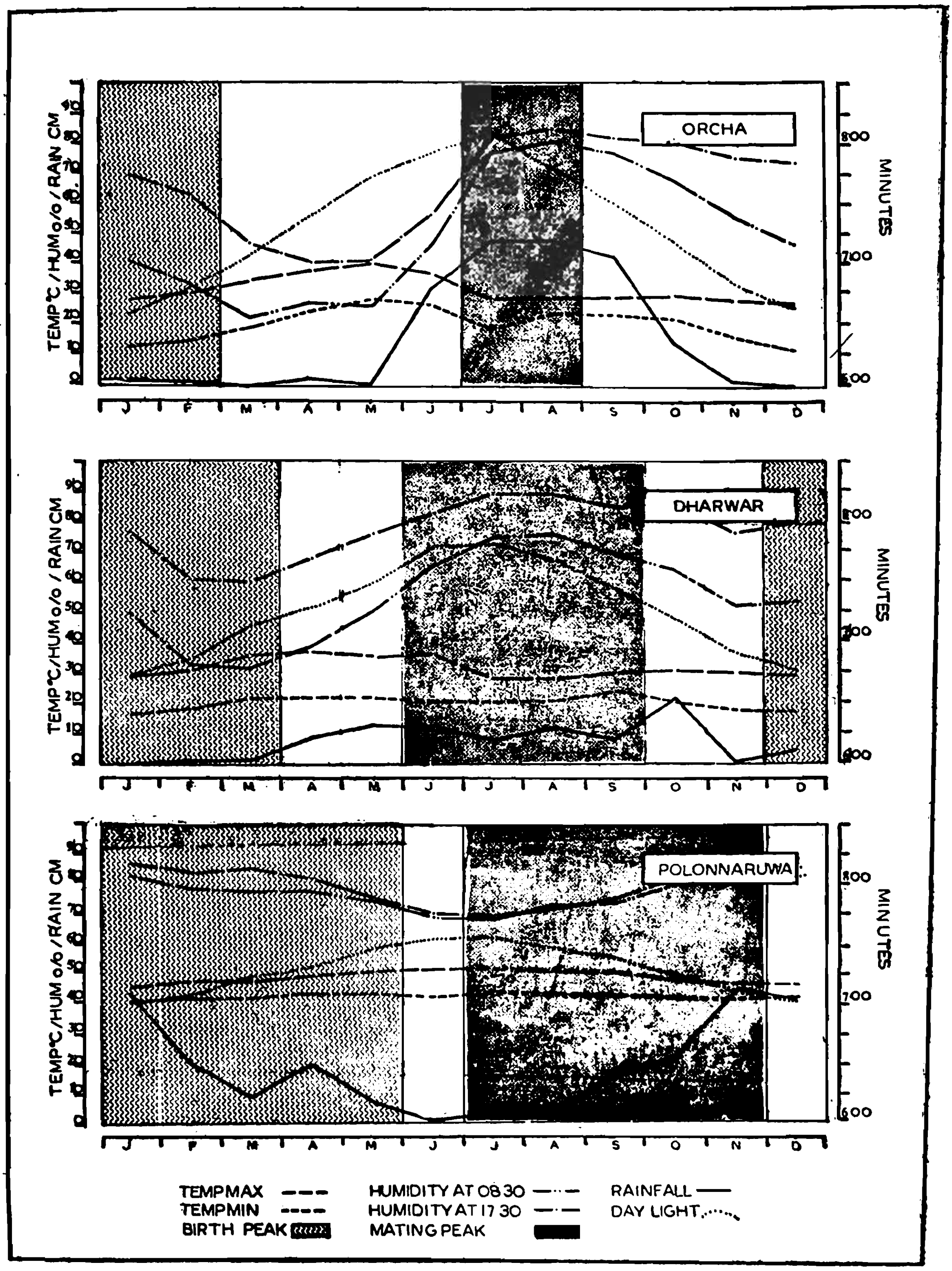
Sheet 2 depicts Jaipur, Sariska, Kaukori



Sheet 3 depicts Jodhpur, Mt. Abu, Singur



Sheet 4 depicts Kanha National Park, Raipur, Gir Sanctuary



Sheet 5 depicts Orcha, Dharwar, Polonnaruwa

Group Studies : Since the pioneering work of Prakash (1958, 1962), extensive field studies on Indian langurs in all regions of the subcontinent have revealed a wealth of information on the ecology and behavior of the species. The reported studies (Table 2) represent all types of social structure ; one-male, multi-male and all-male groups. Group size varies from 1 to 64 individuals and population density from 1.1 to 104 individuals/sq km. The highest number of males in comparison to females was recorded at Raipur (0.81) and lowest at Jodhpur (0.04) (SUGIYAMA, 1964) whereas the infant female ratio is highest at Melemchi (1 : 0.75) and lowest in the Kumaon Hills (1 : 0.22).

Reproductive Cycle : Female langurs reach sexual maturity at from 3-4 years of age (Dolhinow, 1972, Bogess 1976), and their first menstruation occurs at about 3.5 years (Harley, 1983). Menstrual bleeding occurs at about thirty day intervals and estrus midway between menstrual periods. Ovulation takes place on the 9th day from the start of menstrual bleeding. The female shows sign of receptivity during the menstrual cycle two days prior and 2-3 days after ovulation (Newman 1974). During this period females quiver their heads, lower their tails, and present themselves to males. The gestation period is recorded as 200 ± 10 days, or between six and seven months (Harley, 1983), followed by a lactation period of ten to twelve months (Dolhinow, 1972). The birth interval has been reported as 15-30 months ; during much of this time a mother is nursing her previous infant (Hrdy, 1977). The author has observed nursing females presenting to males. Hrdy (1977) has also reported this for a female of Toad Rock troop who gave birth to infants only fifteen months apart. The timing of these patterns of langur cycles vary across the Indian subcontinent, possibly in response to local and regional climatic factors (Vogel, 1977; Curtin and Dolhinow, 1978).

Pattern of Birth : A study of Table 4 reveals that all langur populations display distinct birth peaks, except those in Sariska and Singur. The range of peaks is 1-5 months within the annual cycle, usually in the first half of the year. All populations studied display a single birth peak, except in Jaipur where there are two. The birth peak occurs between December and June.

Because females of this species are polyestrous, there is a more or less uniform pattern of births throughout the year. Various factors may cause a deflection from this uniform pattern, leading to comparatively higher numbers of successful matings and resultant births in a particular period of the year (Moore, 1984). Such factors may be climatic, vegetational, social or psychological, but they are always mediated through the physiology of the species. Such a condition may be brought about in females by the postponement or absence of ovulation, while in the male it may be through delayed spermatogenesis. No single factor is known to be responsible for these phenomena. An attempt has been made here to show how different factors play their roles.

Climatic Factors : A study of the Fig. 2 reveals that, in general, the onset of the peak in mating is associated with comparatively higher degree of precipitation, increasing humidity and decreasing temperature in almost all the study areas. Further investigations suggest two distinct orders in this general pattern. In the first, a mating peak coincides with the advent of the rainy season (Solu Kumbu, Jaipur, Mt. Abu, Gir Sanctuary, Orcha, and Dharwar). In the second, such a peak begins one to three months after the rainy season begins (Simla, Kumaon Hills, Kaukori, Jodhpur, Kanha National Park, Raipur and Polonnaruwa). It is hypothesized that these two different patterns may be attributed to the time rain takes to produce an increase in food supply. Apparently there is no association between the onset of a mating peak and the number of daylight hours.

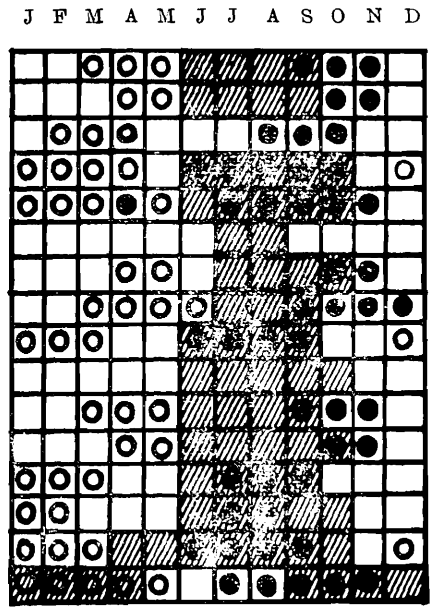
Vegetation : The studies of the feeding ecology of Asian çolobines have demonstrated the importance of diet to patterns of social behavior (Ripley 1968, Yoshiba 1967). Table 3 shows the association between seasonal vegetational changes and langur reproductive events. The data indicate that the numerical abundance of plant species in different phenological stages coincides with the peak period of mating at Jodhpur and Dharwar and with a peak period of birth at Simla. A detailed study on the density of plants consumed by langurs is available only for Dharwar. Yoshiba's 1967 data reveal that five species of plants (*Lantana aculeata* 20.3%, *Zizyphus rugosa* 19.2%, *Zizyphus xylopyra* 9.6%, *Zizyphus oenoplea* 7.3% and *Phyllanthus emblica* 5.1%) constituting more than 70% of the vegetation of the study area (Dharwar) had either fruits, flowers or fresh leaves during the peak mating period. Indirect information of food availability is available for Mt. Abu and Solu Khumbu, through without details on density. These data also support the idea that a mating peak coincides with abundance of food supply (Laws and Vonder Haar Laws, 1984).

Hrdy (1977) wrote that "It would be significant, however, that an infant born in Dec. or Jan. would be taking some solid food by the time of the next monsoon (which is the period of mating peak). Maximum availability of nutritious food would conside then with an

TABLE 4. Various Environmental Factors At The Beginning And End of The Mating Peak In D

AT BEGINNING OF MATING PEAK

	TEMPERATURE °C		HUMIDITY%					
RAIN*	MAX.	MIN.	8 AM	5 PM	DAY	L.	HABITAT	LOCALITY
90 D	20 D	12 D	80 D	83 D	768	D	MOIST TEMPERAT	SIMLA
90 D	18 D	9 D	49 D	61 I	710	D	HIGH ALTD. M. F.	KUMAON HILL
	DATA INSUFFICIENT						HIMALAYA TEMP, F.	MELEMCHI
10 I	15 S	2 I	83 I	—	823	I	CONIFEROUS F.	SOLU KUMBU
10 I	33 I	25 D	79 I	65 I	829	S	CITY DWELLING	JAIPUR
100 D	NO MATING PEAK						DRY SCRUB	SARISKA
100 D	28 D	11 D	69 I	54 S	663	D	CULTIVATED FIELD	KAUKORI
80 S	36 D	24 S	68 D	41 D	771	D	OPEN SCRUB	JODHPUR
5 I	30 D	20 D	64 I	52 I	814	I	DRY SCRUB	Mt ABU
	NO MATING PEAK						VILLAGE DWELL.	SINGUR
80 D	29 I	22 D	83 D	73 D	756	D	DRY & MOIST DEC.	KANHA N. P.
80 D	31 D	21 D	77 D	64 D	713	D	DRY OLD SCRUB	RAIPUR
20 I	29 S	26 S	88 S	89 S	804	S	DECIDUOUS	GIR SANCT.
20 I	28 S	21 I	89 I	74 I	782	D	MOIST DECIDUOUS	ORCHA
26 I	31 S	21 S	83 I	65 I	780	I	DRY DECIDUOUS	DHARWAR
44 I	51 S	43 S	68 I	67 I	754	D	DRY DECIDUOUS	POLONNARUW



* Percent of the total rain till mating peak starts
D Decreasing trend
I Increasing trend
● Mating peak
S Steady trend
O Birth peak
◇ Rainy season

fferent Localities.

AT END OF MATING PEAK

SUBSPECIES	TEMPERATURE °C MAX.	MIN.	HUMIDITY % 8 AM	5 PM	DAY L.
SCHISTACEUS	15 D	7 D	36 I	58 S	652 D
.S ENTELLUS	15 D	6 D	46 I	64 D	660 D
SCHISTACEUS	DATA INSUFFICIENT				
ACHILIES	9 D	7 D	33 I	66	661 D
ENTELLUS	29 D	13 D	53 I	35 I	663 D
ENTELLUS	NO MATING PEAK				
SCHISTACEUS	25 D	10 D	76 I	55 I	633 D
ENTELLUS	25 D	12 D	61 D	35 D	636 D
ENTELLUS	24 S	17 S	82 D	75 D	762 D
ENTELLUS	NO MATING PEAK				
ENTELLUS	31 D	17 D	75 D	53 D	665 D
ENTELLUS	29 D	15 D	60 D	40 D	677 D
ENTELLUS	30 I	25 D	86 D	84 D	754 D
ANCHISES	29 S	24 S	85 D	80 D	778 D
ACHATES	30 S	20 S	85 D	68 D	746 D
A THERSITES	46 S	41 S	88 I	81 I	709 D

exceedingly vulnerable transition point in the life of a weaning infant." It is noteworthy that in the Himalayas the birth season comes in middle to late winter and spring. "Curtin (1975) notes that this places an additional burden on mothers at a time when food shortages are most severe. However the advantage to the growing infant of abundant moist foods from spring through fall (which is again the period of mating peak) may outweigh the hazards of winter birth" (Bishop, 1979).

Discussion

The factors responsible for peak mating activities in langurs occur at different levels. Major environmental factors such as phenological patterns, modified by the pattern of rainfall, may act as a general timing influence that interacts with intrinsic mechanisms. Final co-ordination between the individuals within a group at the start of mating may then depend upon the female stimuli activating male responses and interactions between females. To confirm these hypotheses, information is needed on the influence of such factors as rainfall pattern and subsequent phenological changes based on field studies of longer duration.

All climatic variables considered independently fail to reveal any correlation between a mating peak and climatic factors. However, it is suggested that the seasonal pattern of rainfall that follows a marked drop in temperature, increase in humidity and change in phytophase agrees with the results of other studies available (*Presbytis senex*, Rudran, 1973 ; *Macaca mulatta*, Koford 1965). The amount of rain that could initiate a mating peak varies from 5% in dry scrub habitat to 100% where the habitat is cultivated field (Table 4). Though no generalization could be made with respect to the kind of habitat and amount of rainfall required to initiate a peak, it is most likely the result of a combination of more than one variable, including precipitation.

Conclusions

The following general points emerge from the study.

1. There is no simple correlation of latitude with the onset of peak in conception, and hence with number of daylight hours.

2. Different amounts of rain could initiate the breeding activities. It may range from 5% to 100% of the total rainfall in the particular locality. Probably it depends on the percentage of rainfall that could produce desired effects, which may vary from place to place and individual to individual.

3. There are two pattern, either mating peak coincide with peak in rainfall or it follows 1-3 months after peak period of rainfall. The probable reason for these two patterns is the different amount of time that rain takes to increase available food, cause a drop in annual temperature and increase humidity.

4. The climatic data, especially distinct peaks in rainfall at Sariska and Singur suggest that studies of longer duration may reveal the existence of peak periods of breeding in these localities.

SUMMARY

The reproductive activities of *Presbytis entellus* are correlated with various environmental factors. It was found that, in general, the mating peak in the annual reproductive cycle of langur populations is associated with higher degress of precipitation, increasing humidity and decreasing annual temperature. Within this trend there are two distinct patterns : (1) peaks in mating and rainfall coincide, or (2) the peak in mating follows one to three months after the peak period of rainfall.

Key words : *Presbytis entellus* : Indian subcontinent ; reproductive cycle, environmental factors.

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