Observations on the breeding biology of the Western Ghats squirrel, *Funambulus tristriatus* Waterhouse *

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Certains aspects de la biologie de la reproduction ont été étudiés chez un écureuil des Ghats occidentaux, *Funambulus tristriatus* Waterhouse, de novembre 1977 à octobre 1979, dans le sud de l'Inde (Vittal, 12°30' N, 74°80' E). Cet écureuil se reproduit toute l'année, avec un pic au cours de l'été, de décembre à avril.

La moyenne des portées a été de 2,5 ± 0,6, mais à la naissance les portées avec 2 jeunes ont été les plus fréquentes (67 %). Il semble qu'il y ait des pertes après l'implantation et du cannibalisme dans les populations naturelles de cet écureuil. Le nouveau-né est aveugle et sa peau est rose et transparente. Le jeune commence à consommer des aliments secs et acquiert la couleur du corps de l'adulte dès le 6e jour.

INTRODUCTION

The Western Ghats squirrel, *Funambulus tristriatus* Waterhouse, is a fairly common rodent found in the forest and cultivated fields along the west coast in south India (Moore and Tate, 1965). Ellerman (1961), Moore and Tate (1965) and Biswas and Tiwari (1969) studied the distribution, and Rao *et al.* (1972) described the karyotype of this squirrel. Bhat *et al.* (1981) identified *F. tristriatus* as one of the rodent pests of cacao, *Theobroma cacao* L. The knowledge on the biology of this species was scanty. Hence, studies were made on its population dynamics, breeding biology and feeding behaviour from January 1976 to October 1979. This communication carries information on the breeding biology of the Western Ghats squirrel.

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STUDY AREA AND CLIMATE

The study was carried out around Vittal (12°30'N, 74°80'E) in the Dakshina Kannada district of Karnataka, India. Vittal is 5.3 m above the mean sea level and comprises many low hillocks and valleys. About one third of the land is irrigated with areca palm (*Areca catechu* L.) and paddy (*Oryza sativa* L.) as the main crop. The remaining land has sparse vegetation with *Anacardium occidentale* L., *Aporosa lindleyana* Baill., *Eugenia jambolana* Lam., *Strychnos nux-vomica* L., *Calycopteris floribunda* Lamk., and *Ixora coccinia* L. forming the major plant community.

Vittal has a tropical climate with well defined summer and rainy seasons. About 70 per cent of its mean annual rainfall of 45 cm is received between June and August. The day temperature is lowest (about 29 °C) and relative humidity highest (up to 93 %) again during June to August. Occasional showers occur from September to November. The summer is from January to May, the time when the temperature reach a maximum of 35 °C. Nights are comparatively cooler (about 18 °C) from December to February.

MATERIALS AND METHODS

Breeding season

Specimens of the Western Ghats squirrels were collected every month from the adjoining areas of Vittal using snap traps (20 × 12 cm) from November 1977 to October 1979. The following aspects were studied and records maintained for each specimen: For males, the measurements and weights of testes, the weights of epididymus and the measurements of seminal vesicles were recorded. The epididymal smears were examined for the presence of sperms. For females, the physical appearance of the vagina, the uterus and mammae was noted. The embryos, if present, were counted separately of both horns.

The weights of the testis and opididymis were taken on a top-pan balance (sensitivity 0.002 g). A male squirrel was considered to be reproductively active if sperms were present in the smears of its epididymis and a female considered mature if its vagina was perforate as suggested by Tamarin (1977).

Postnatal development

A total of nine pregnant female Western Ghats squirrels was collected during the main breeding season in 1978 and kept under observation in the laboratory in separate wiremesh cages (70 × 30 × 30 cm). Each cage had a

central breeding chamber and two sliding doors through which the mother could be removed while examining its litter. The pregnant females were given nesting materials from the nests of other squirrels in the wild. Grains of paddy and water were provided *ad libitum*. Fruits such as the banana and papaya, and tubers of sweet potato and cassava were given once in three days.

The newly born animals were sexed on the basis of the presence of scrotal pigmentation, weighed to the nearest 0.25 g and measured on the day of birth. Thereafter, the young ones were weighed every third day up to 150 days of postnatal development. Linear measurements of the head and body, ears, hind feet, and tail were recorded to the nearest mm. From their 50th day the young squirrels were anaesthetized prior to examination to ensure easier handling. The development of important morphological characters like the unfolding of the pinnae, development of stripes on the back, eruption of incisor, opening of the eye, development of hairs etc. was recorded. The instantaneous growth rates (IGR) were calculated using the following formula (Willan and Meester, 1978):

$$IGR = \frac{lnm_2 - - lnm_1}{t_2 - - t_1}$$

where lnm_2 and lnm_1 were natural logarithms of mean measurements recorded at times t_2 and t_1. The period $t_2 - - t_1$ was taken as three days up to the 90th day of development and thereafter as six days.

RESULTS AND DISCUSSION

Breeding season

The male Western Ghats squirrels with fully functional testes were encountered during all the months (Fig. 1). Out of the 62 males autopsied, 55 (88.7 %) had sperms in their epididymal smears. Their body weights ranged from 112.0 to 176.0 g (mean 139.16 ± 1.78 g). Squirrels without sperms in the epididymal smears weighed from 82.0 to 106.0 g (mean 94.36 ± 4.60 g). The weights and measurements of the testes and accessory sex glands of the adult and the subadult squirrels are furnished in Table 1. There was a close correlation

TABLE. 1. — Weights and measurements of the testis and accessory reproductive organs of the male Western Ghats squirrel (for adults and sub-adults).

	Testis length (mm)		Testis breadth (mm)		Testes weight (g)	S.vesicle length (mm)		S.vesicle breadth (mm)		Epididymidis weight (g)
	right	left	right	left		right	left	right	left	
Adult mean± SE[1]	10.00± 0.10	10.05± 0.12	7.10± 0.11	7.08± 0.11	1.02± 0.02	15.08± 0.04	14.93± 0.45	10.17± 0.45	9.95± 0.44	0.40± 0.01
S.adult mean± SE[2]	5.50± 0.35	5.52± 0.28	3.79± 0.18	3.84± 0.10	0.09± 0.08	8.85± 0.36	9.07± 0.32	4.08± 0.23	3.91± 0.20	0.04± 0.01
't' between 1 & 2	27.7	29.4	21.9	20.9	9.63	10.4	9.76	10.12	10.27	16.97

between the weight of the testes and that of the epididymes and the relation approximated to a straight line (Fig. 2).

In the south Indian palm squirrel, *F. palmarum* also the male exhibited an uninterrupted sexual activity (Prasad, 1951). Regression of testes was revealed only in seasonally breeding squirrels (Layne, 1954; Seth and Prasad, 1969; Brown and McGuire, 1975; Morton and Gallup, 1975; Viljoen, 1977*b*). The occurrence

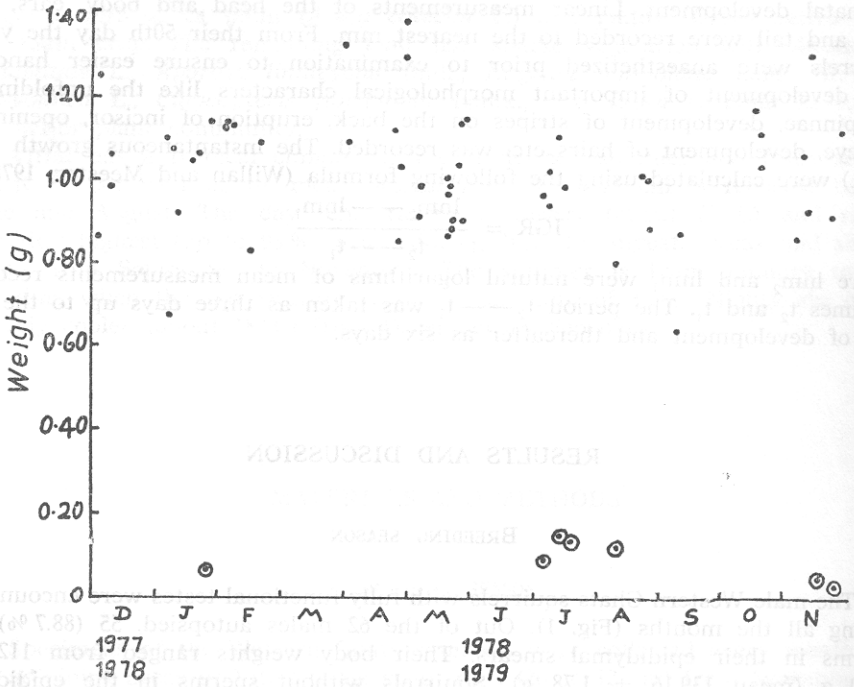

Fig. 1. — Scatter diagram showing the variation in the weight of the testes (paired weight per 100 g body weight) of those withs (upper symbols) and without (lower symbols) sperms in the epididymes, in different months. N = 62.

of sexually active males in the population alone should not be considered to be the criteria of judging the length of the breeding season in squirrels. For example, in the grey squirrel, *Sciurus carolinensis,* fecond males were found in the population all the year round but the females exhibited seasonality in breeding (Pudney, 1976).

Out of the 195 females Western Ghats squirrels trapped during the period of this study, 167 (85.6 %) had perforate vaginae. Squirrels with perforate vaginae weighed between 80.0 and 174.0 g (mean 133.52 ± 1.04 g) and those with imperforate vaginae 33.0 to 107.0 g (mean 85.23 ± 3.66 g). Of the 167 perforate females 22 (13.2 %) were found to be pregnant and 30 (18.0 %) lactating. The percentage of perforate females pregnant and/or lactating in each month is depicted in

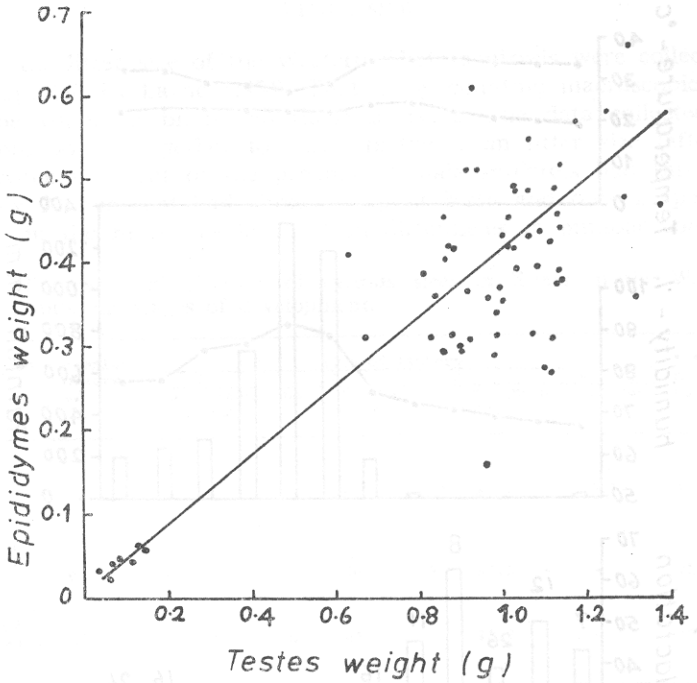

Fig. 2. — Scatter diagram showing the relation between the weight of the epididymes (paired weight per 100 g body weight) and the weight of the testes (paired weight per 100 g body weight). The straight regression line for these points is drawn. N = 62.

Fig. 3. The Western Ghats squirrels bred all the year round with a peak during the summer season from December to May. The number of pregnant and/or lactating females were few from June to August, the period of heavier rainfall. Similarly, pregnant females were not observed in the rodents of Ivory Coast during the periods of highest rainfall (Ballier *in* Delany, 1972). Like the Western Ghats squirrel the south Indian palm squirrel also breed throughout the year (Prasad, 1950). The uniformly warmer temperature with poorly marked winter at Vittal could be one of the reasons for the absence of any distinct seasonality in breeding of the Western Ghats squirrel. The effect of temperature on breeding was clearly noticed in the case of the northern palm squirrel, *F. pennanti*, which restricted its breeding to the hot rainy season avoiding the much cooler winter (Louch *et al.*, 1965 ; Purohit *et al.*, 1966).

Mating behaviour

Sexual chasing and mating of the western Ghats squirrel were observed in four occasions, between February and September 1979, once each on the trunk of a coconut palm, the branch of a jack tree, the fence of a garden and the roof of a building. Activities such as chasing, sniffing the face and external genitalia of the female and mounting were observed. In one instance, only one

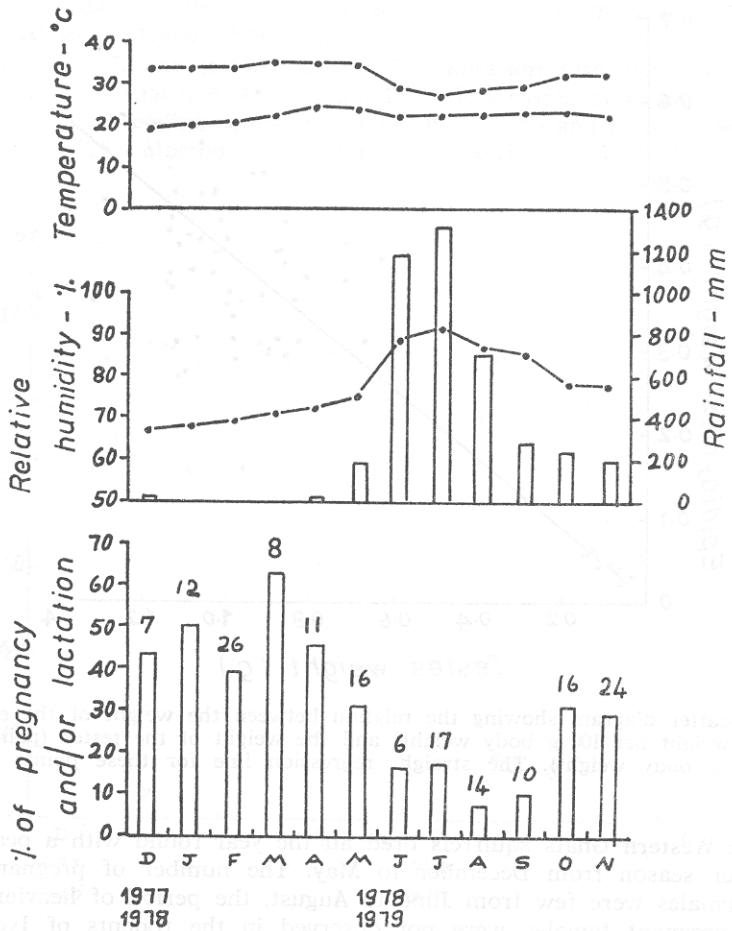

Fig. 3. — Percentage of total perforate female Western Ghats squirrels pregnant and/or lactating in each month in the study area (sample size denoted on top). Data accumulated over two years and correlated with the weather conditions.

male was involved in courtship chasing. In the other three cases two to three males were involved. Chasing was very quick and it was often difficult to distinguish between the males. When more than one male were courted a female conflicts between rivals occurred. The female watched this quarrel from a distance. The successful male quickly approached the female and the others moved away. The male sniffed the face of the female uttering a mating call which could be described as 'chi-chi' mating call. The male moved to her rear and sniffed her perinum. She then raised her rear, moving her tail to a side. In the attempt to mount, the female sometimes slipped and moved forward. In such cases the male sniffed the female's face again till she attained a position in which the male could clasp her flanks firmly with his forelegs. He then performed fast pelvic thrusts for a short period and copulated. Copulation lasted 15-20 seconds. The pair then separated and autogroomed their external genitalia.

Litter size

Data on the litter size of the Western Ghats squirrels were collected by the methods suggested by Layne (1954). That is by counting macroscopically visible embryos, the young at birth and those in nests. The data collected on these methods were pooled together to calculate the mean litter size (after Quimby, 1951). Ninetyone per cent of the pregnant female squirrels had three embryos, whereas only 33 per cent had three young at birth and only 22 per cent had three young in the nests (Table 2). Such differences in number could possibly

TABLE 2. — Frequency distribution of various sizes of litters in the Western Ghats squirrel in different stages of development.

Source of data	Samples observed	Size of litters								Total no.of young	Mean litter size 1 SE
		1		2		3		4			
		no.	frequency	no.	frequency	no.	frequency	no.	frequency		
By counts of embryo	11	-	-	-	-	10	90.9	1	9.1	34	3.09± 0.29
By counts of young at birth	9	-	-	6	66.7	3	33.3	-	-	21	2.33± 0.47
By counts of young in nests	9	1	11.1	6	66.7	2	22.2	-	-	19	2.11± 0.57
Total	29	1	3.45	12	41.38	15	51.72	1	3.45	74	2.55± 0.62

be due to the resorption of embryos as observed in several other rodents (Spillett, 1968; Morton and Gallup, 1975; Tamarin, 1977; Rao, 1981).

Cannibalism of their young by confined females was noted in several instances in the Western Ghats squirrel (Bhat, 1980). It was not known if such a behaviour was common in the natural population of this squirrel. However, cannibalism could be one of the reasons for the loss of young after birth. Cannibalism was already reported in the wild populations of some rodents (Prasad, 1954; Donald and Smith, 1975). Fox (1975) opined that cannibalism was an adaptive behaviour which along with several other factors maintained the number of young in the family within the limits of food supply.

Young and postnatal development

The newly born Western Ghats squirrel was pinkish with translucent skin through which the viscera and the cranial sutures were visible. The body was not covered with any type of hair except vibrissae. Eyes were closed and appeared as dark specks. The pinnae were folded and the external auditory meatus was closed. No trace of stripes was visible on the dorsum. Nails were transparent. Length of the head and body of 21 young at birth was 42-51 mm, tail 22-32 mm, hind foot 9-11 mm and weight 4.5-7.25 g (Table 3).

The growth and development of different morphological characters were recorded for three litters (seven young). Pinnae of the ears which were folded at birth unfolded, and the stripes on the dorsum were visible on the third day.

TABLE 3. — Weights and measurements of 21 new born young Western Ghats squirrel.

Litter	Young	Body weight (g)	Length (mm) of		
			Head and body	Tail	Hind foot
I	1	5.0	46	23	9
	2	6.0	50	25	10
II	1	5.0	45	25	9
	2	6.0	48	29	10
III	1	5.25	47	23	9
	2	6.0	48	27	10
IV	1	6.25	49	29	10
	2	7.0	51**	31	11
V	1	5.0	43	24	9*
	2	6.25	49	25	10
	3	5.5	47	25	10
VI	1	4.5*	42*	22*	9
	2	6.5	51	26	11
	3	5.5	47	24	10
VII	1	6.0	48	28	10
	2	7.25**	50	32**	11**
VIII	1	5.5	48	29	10
	2	6.25	49	31	11
IX	1	5.0	44	26	9
	2	6.5	48	29	11
	3	5.75	46	28	10
Mean ± 1 SE		5.81± 0.15	47.43± 0.53	26.71± 0.63	9.95± 0.16

* Minimum ** Maximum

The eye-slits also appeared on this day. The body of the young had fine hairs on the twelfth day. The upper and lower incisors erupted during the third week. Eyes opened between the days 24 and 30. By the sixtieth day of development the young had attained the colouration of an adult (Table 4).

The growth data for cage reared (n = 7) Western Ghats squirrels are graphically presented in Fig. 4. The body weights and linear measurements improved quickly up to day 72, but slowed thereafter. The length of the hind feet and pinnae attained more than 90 per cent of their adult size by the sixtieth day of development. The young reached about 70 per cent of the adult length by the sixtieth day. The rate of increase in the' body weight was very slow and attained only less than 35 per cent of the adult weight on the day 60.

During the first 12 days of development the IGR was highest for head and body, but tail grew faster between days 12 and 60 (Fig. 5). From day 60 to 72 the IGR was highest, again, for the head and body. For the head and body and for the hind feet the growth rates were highest up to day 12, but for tail it was from day 36 to 48. The rate of growth for pinnae was even up to day 42 with the fastest growth rate between day 24 and 36. The young squirrel attained weight slowly and reached its maximum bythe sixtyfifth day. The rate of growth was almost negligible from the eightieth day onwards in the pinnae and from one hundred and tenth day onwards in the hind feet. However, the length of the tail, head and body, and body weight increased up to the last day (153rd day) of observation.

In outward appearance of the new born Western Ghats squirrel ressembled those of the other sciurids (Layne, 1954; Morton and Tung, 1971), except that

TABLE 4. — Days of occurrence of some events during the postnatal development of the Western Ghats squirrel in captivity.

Occurrence of events	Days after birth
1. Pinnae unfolded	3
2. Stripes became visible	3
3. Eye ball developed transverse slit	3
4. Circles on the tail became visible	9-12
5. Lower incisor erupted	9-15
6. Pelage development began	12
7. Upper incisor erupted	18-21
8. Tail hairs showed black and white bands	21
9. Scrotal sac became darker	24
10. Eye opened	24-30
11. Red hairs developed on the ventral surface of the tail	27-30
12. White hairs developed on the ventral surface of the body	30
13. First yellow band developed on the hairs of the tail	39-42
14. Second black band developed on the hairs of the tail	42-48
15. Second yellow band developed on the hairs of the tail	48-54
16. Formation of enamel on the incisors completed	57-66
17. Consumed solid foods	60-69

of the bush squirrel, *Paraxerus cepapi* (Viljoen, 1977*a*) which were born in a more advanced stage. Table 5 furnishes a summary of the development of

TABLE 5. — Gestation period and development of different morphological characters during the postnatal development (in days except otherwise noted) of some Sciuridae.

Species	American Red Squirrel	Fox squirrel	Bush squirrel	California ground squirrel	Flying squirrel	European Red squirrel	Grey squirrel	Northern palm squirrel	Western Ghats squirrel
References	Layne, 1954	Allen, 1943	Viljoen 1977a	Fitch, 1948	Muul, 1970*	Eibl-Eiberfeldt 1951*	Horwich 1972*	Purohit et al. 1966	Present study
Gestation period	40	45	56	30	40	38	44	42	-
Pinnae unfolded	-	-	1	-	2	1	4	1st week	3 days
Eyes opened	26-29	5 weeks	1-8	4.5weeks	28	31-32	28-30	15-25	24-30
Lower incisor erupted	21	-	1	-	14	23	19-21	1-2weeks	9-15
Upper incisor erupted	42	-	7	-	26	41	31-42	2-4weeks	18-21

* In: Viljoen, 1977a.

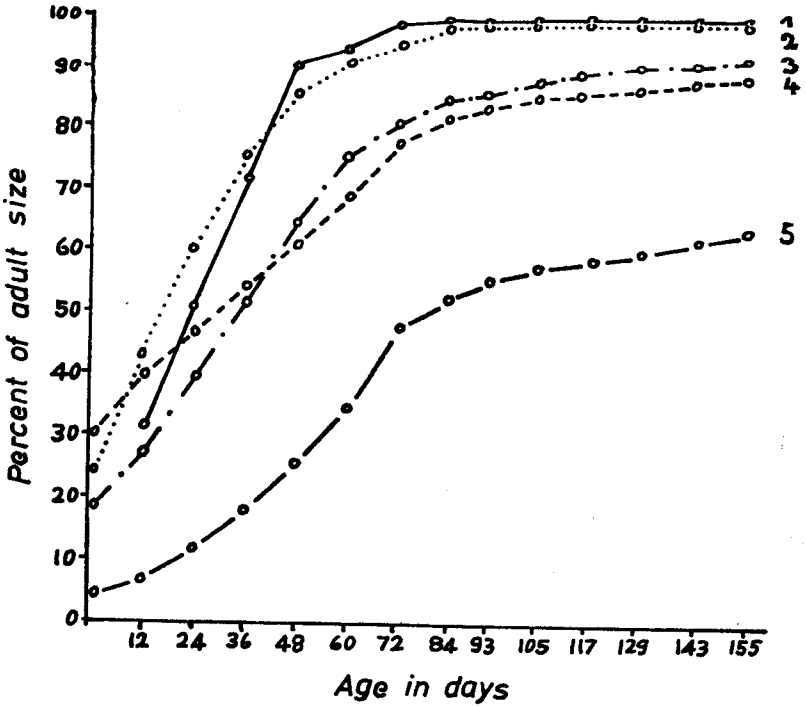

Fig. 4. — Body weight and linear measurements of young Western Ghats squirrel in relation to adult size. N = 7. (3, tail; 4, head and body; 1, hind foot; 5, body weight; 2, pinna).

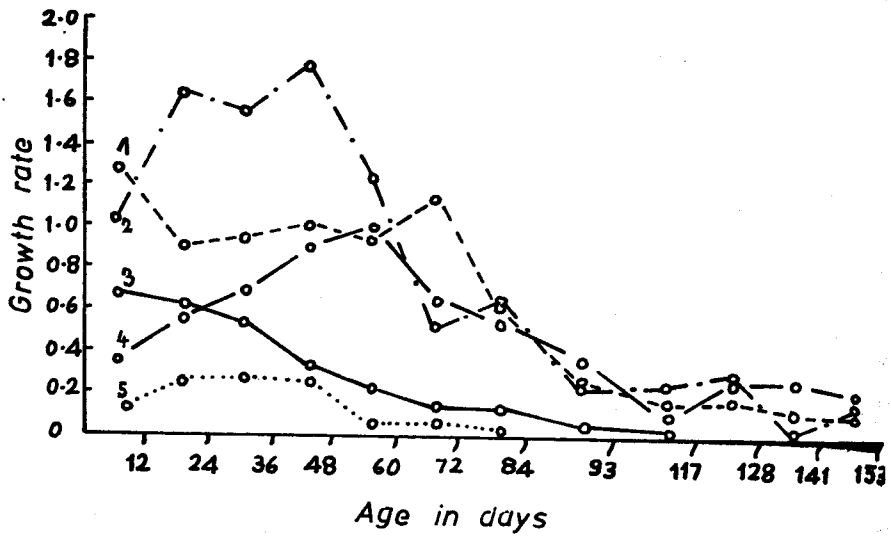

Fig. 5. — Instantaneous growth rates of body weight and linear measurements of young Western Ghats squirrel. N = 7. (2, tail; 1, head and body; 3, hind foot; 4, body weight; 5, pinna).

different morphological characters in some sciurids. The fastest rate of development was noticed in the bush squirrel. This according to Morton and Tung (1971) was due to the longer gestation period of the bush squirrel.

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SUMMARY

Observations were made on certain aspects of the breeding biology of the Western Ghats squirrel, *Funambulus tristriatus* Waterhouse in Vittal (12°30' N, 74°80' E), south India from November 1977 to October 1979. This squirrel bred all the year round with a peak during summer from December to April. The mean litter size for the Western Ghats squirrel was 2.5 ± 0.6, but litters with two young were common (67 %) at birth. Post implantation losses and cannibalism were suspected to occur in the natural population of this squirrel. The new born young was blind and the skin was pinkish and translucent. The young started consuming solid foods and acquired the body colouration of the adult by the sixtieth day of development.

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