

BREEDING HABITS AND ASSOCIATED PHENOMENA IN SOME INDIAN BATS

Part VI — *Scotophilus heathi* (Horsefield) — Vespertilionidae¹

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Scotophilus heathi (Horsefield) from Trichur, Kerala State, has an annual reproductive cycle. Copulation occurs during the second week of November and ovulation and fertilization by the stored spermatozoa occur in the last week of December. Every female in the colony conceives in December and young ones are delivered during the following April and the first week of May. Lactation continues until August. Animals are sexually quiescent during the rest of the year. The two uterine cornua are normally functional and carry an embryo each during each cycle. The gestation period varies in different animals from 100 to 130 days. The females far outnumber the males in the adult stage although at birth the sex ratio is even.

INTRODUCTION

Scotophilus heathi is one of the species chosen for detailed study under the project of studies on the breeding habits of Indian bats. This species has been chosen not only as a representative from an area from which the breeding habits of no bat has been so far reported but also because this species presents unusual features of reproduction. Detailed reviews of earlier literature on bat reproduction have been given (Gopalakrishna, 1947, 1948, 1949, 1955; Madhavan, 1971; Gopalakrishna and Choudhari, 1977; Gopalakrishna and Rao, 1977).

MATERIAL AND METHODS

Most of the specimens of *Scotophilus heathi*

examined for the present study were collected from under the tiles of roofs of houses. A few specimens were also collected from under the leaves of palmyra trees, from the belfry of churches and on one occasion from a well. All specimens were collected in and around Trichur, Kerala (approximately 10°N., 76.3°E.). The animals were collected at frequent intervals commencing from April 4, 1971 and until February 5, 1978 except during the year 1974. Altogether 957 specimens were studied for the present report.

Scotophilus heathi is a large bat for a microchiropteran with an adult body weight of 36 to 39 g (the females attaining a higher weight than the males, a wing-span of c. 40.0 cm, forearm length of c. 6.5 cm, head length of c. 2.5 cm and ear pinna length of c. 1.5 cm. The specimens were collected from their roosts with the help of a pair of long forceps and after killing with chloroform they were weighed in a sensitive spring balance. Observations on the disposition of the external genitalia, mammary teats in the females, and po-

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sition of the testes in the males were recorded. The genital organs and the accessory structures were dissected out and fixed in different fixatives. After fixation for 24 hours the tissues were preserved in 70% alcohol. The tissues were dehydrated by passing through graded series of ethanol, embedded in paraffin and sectioned at thickness of 6 to 10 μ . The testes were uniformly cut at 10 μ . The sections were stained with Ehrlich's haematoxylin, counter-stained with eosin and mounted in DPX.

The character of a group of specimens collected on a given calendar date is almost the same during the different years when the collections were made. Hence, in the following descriptions only the date and month are mentioned where pertinent except where the mention of the year has a special significance. A detailed collection diary was maintained with descriptions of individual specimens. Table 1 gives the summary of the collection diary and Table 2 gives the monthwise distribution of collections.

OBSERVATIONS AND DISCUSSION

1. GENERAL NOTES ON *Scotophilus heathi*

This species occurs in small groups of 5 to 15 specimens which lie huddled together. There may be several clusters of specimens occupying different locations in the same house. During April, May, June and July the males were sometimes found 'sitting' away from the females although in the same house. The animals emerge from their roosts a little before sunset and take a dive almost to the ground level before they take to the sky. They fly about near the roosting place for a considerable time before flying out to distant places. The roost is empty by about 7 o'clock in the evening. The suckling mothers leave the young ones in the roosts before flying out in the even-

ing for foraging. The mother vigorously shakes her body and actively pushes the young from its hold to the mammary nipple. Several times during the night the adult specimens visit the roosts where the young ones are left behind. They finally return to the roosts a little before sunrise. The mothers carry away the young ones if the roost is disturbed and roost in some other place, often returning with the young ones to the old roost two or three days later. Day light is not an impediment for them to roost because they are found roosting in well-lit areas in the roofs of the houses. The young ones assume an oblique posture with the head towards the mother's head while sucking. The young ones with body weights of 24 g and below are not able to execute sustained flights, but fall to the ground after flying a few yards.

The adult specimen has brown fur on the dorsal surface and bright yellow fur on the ventral surface of the body. The juveniles have dark brown fur on the dorsal surface and yellowish grey fur on the ventral surface of the body. Several parous adults have brick red-yellow fur on the ventral surface of the body. *Scotophilus heathi* does not tolerate the presence of other species of bats in the roost. On a few occasions a specimen of *Pipistrellus mimus mimus* was introduced into a cage in which *Scotophilus heathi* specimens were present. But it was immediately attacked and killed by an adult *Scotophilus heathi*. No other species of bats could be found in the houses occupied by *Scotophilus heathi*. The specimens remain in partial torpidity during daytime throughout the year.

Although normally two young ones are delivered each time, there were a few instances when only one was produced. The newly born young is reddish in colour with naked skin and adherent eyelids. A pair of pectoral mammary glands are present, one on either side,

BREEDING HABITS OF SOME INDIAN BATS—VI

TABLE 1
SUMMARY OF COLLECTION DIARY

Date	Males				Females						Grand Total
	Immature		Adult	Total	Immature		Adult			Total	
	Attached	Free			Attached	Free	Non-preg- nant	Preg- nant	Lacta- ting		
1	2	3	4	5	6	7	8	9	10	11	12
4-1-76	—	—	—	—	—	—	—	1	—	1	1
7-1-78	—	—	1	1	—	—	—	—	—	—	1
9-1-77	—	—	3	3	—	—	—	5	—	5	8
12-1-77	—	—	2	2	—	—	—	9	—	9	11
16-1-77	—	—	2	2	—	—	—	4	—	4	6
17-1-77	—	—	—	—	—	—	—	9	—	9	9
18-1-73	—	—	1	1	—	—	—	3	—	3	4
19-1-77	—	—	3	3	—	—	—	2	—	2	5
20-1-72	—	—	—	—	—	—	—	6	—	6	6
22-1-77	—	—	—	—	—	—	—	7	—	7	7
24-1-76	—	—	—	—	—	—	—	4	—	4	4
26-1-77	—	—	—	—	—	—	—	7	—	7	7
29-1-72	—	—	3	3	—	—	—	3	—	3	6
30-1-77	—	—	1	1	—	—	—	7	—	7	8
4-2-77	—	—	3	3	—	—	—	10	—	10	13
5-2-78	—	—	2	2	—	—	—	7	—	7	9
6-2-77	—	—	3	3	—	—	—	4	—	4	7
9-2-77	—	—	2	2	—	—	—	6	—	6	8
12-2-77	—	—	2	2	—	—	—	2	—	2	4
16-2-77	—	—	5	5	—	—	—	6	—	6	11
19-2-77	—	—	1	1	—	—	—	7	—	7	8
24-2-77	—	—	1	1	—	—	—	3	—	3	4
26-2-72	—	—	2	2	—	—	—	4	—	4	6
27-2-77	—	—	1	1	—	—	—	6	—	6	7
3-3-77	—	—	1	1	—	—	—	2	—	2	3
4-3-73	—	—	—	—	—	—	—	2	—	2	2
5-3-77	—	—	—	—	—	—	—	10	—	10	10
6-3-76	—	—	—	—	—	—	—	2	—	2	2
10-3-73	—	—	—	—	—	—	—	1	—	1	1
11-3-72	—	—	3	3	—	—	—	2	—	2	5
13-3-77	—	—	1	1	—	—	—	3	—	3	4
14-3-76	—	—	—	—	—	—	—	3	—	3	3
19-3-72	—	—	8	8	—	—	—	7	—	7	15
23-3-77	—	—	—	—	—	—	—	3	—	3	3
28-3-77	—	—	1	1	—	—	—	2	—	2	3
29-3-77	—	—	2	2	—	—	—	10	—	10	12
31-3-72	—	—	5	5	—	—	—	3	—	3	8

1	2	3	4	5	6	7	8	9	10	11	12
31-3-73	—	—	—	—	—	—	—	1	—	1	1
1-4-76	—	—	1	1	—	—	—	2	—	2	3
4-4-71	2	—	—	2	1	—	—	—	2	3	5
4-4-77	—	—	—	—	—	—	—	2	—	2	2
5-4-72	—	—	4	4	—	—	—	9	—	9	13
5-4-77	—	—	—	—	—	—	—	4	—	4	4
7-4-72	1	—	—	1	—	—	—	3	1	4	5
7-4-77	—	—	1	1	—	—	—	2	—	2	3
8-4-77	—	—	—	—	—	—	—	5	—	5	5
9-4-72	3	—	—	3	1	—	—	—	1	2	5
11-4-76	—	—	—	—	—	—	—	2	—	2	2
13-4-72	—	—	5	5	—	—	—	—	—	—	5
13-4-77	—	—	2	2	—	—	—	6	—	6	8
14-4-76	1	—	—	1	1	—	—	3	1	5	6
15-4-72	4	—	—	4	5	—	—	1	6	12	16
17-4-77	—	—	—	—	—	—	—	8	—	8	8
19-4-73	—	—	—	—	—	—	—	1	—	1	1
20-4-72	5	—	—	5	3	—	—	1	5	9	14
20-4-76	3	—	—	3	1	—	—	1	2	4	7
21-4-75	—	—	—	—	—	—	—	2	—	2	2
25-4-76	1	—	—	1	3	—	—	1	3	7	8
25-4-77	6	—	—	6	4	—	—	2	4	10	16
1-5-72	4	2	1	7	4	—	—	—	4	8	15
2-5-76	2	1	—	3	2	1	—	—	2	5	8
3-5-77	5	—	—	5	3	—	—	—	4	7	12
10-5-72	—	2	3	5	3	—	—	—	2	5	10
10-5-76	2	—	—	2	4	—	1	—	2	7	9
17-5-76	2	1	—	3	5	—	1	—	3	9	12
20-5-72	—	—	3	3	—	1	3	—	2	6	9
21-5-75	—	—	2	2	—	—	—	—	—	—	2
22-5-77	1	11	—	12	3	1	—	—	2	6	18
24-5-77	—	—	—	—	—	1	—	—	—	1	1
26-5-77	—	5	2	7	—	1	2	—	4	7	14
30-5-72	—	2	3	5	—	—	3	—	3	6	11
30-5-76	1	2	1	4	—	1	1	—	3	5	9
31-5-75	—	1	2	3	—	1	—	—	—	1	4
5-6-77	—	—	—	—	—	3	1	—	5	9	9
10-6-72	—	—	6	6	—	—	—	—	—	—	6
13-6-76	—	—	4	4	—	—	1	—	1	2	6
15-6-72	—	—	—	—	—	—	1	—	1	2	2
20-6-72	—	—	1	1	—	—	1	—	1	2	3
26-6-77	—	2	—	2	—	2	1	—	4	7	9
27-6-76	—	—	—	—	—	—	—	—	1	1	1
28-6-72	—	—	2	2	—	—	1	—	—	1	3
30-6-72	—	—	2	2	—	—	2	—	1	3	5
3-7-77	—	—	4	4	—	1	1	—	2	4	8

BREEDING HABITS OF SOME INDIAN BATS—VI

1	2	3	4	5	6	7	8	9	10	11	12
9-7-77	—	1	2	3	—	2	1	—	—	3	6
11-7-72	—	—	1	1	—	—	2	—	—	2	3
14-7-72	—	—	2	2	—	—	5	—	—	5	7
17-7-76	—	—	3	3	—	—	3	—	3	6	9
17-7-77	—	2	—	2	—	7	1	—	6	14	16
20-7-75	—	—	—	—	—	—	6	—	—	6	6
24-7-77	—	2	—	2	—	2	1	—	—	3	5
6-8-77	—	—	1	1	—	2	—	—	2	4	5
15-8-72	—	—	—	—	—	—	2	—	—	2	2
15-8-76	—	—	2	2	—	—	2	—	—	2	4
18-8-73	—	—	3	3	—	—	3	—	—	3	6
21-8-72	—	—	—	—	—	—	1	—	—	1	1
21-8-75	—	—	1	1	—	—	—	—	—	—	1
21-8-76	—	—	3	3	—	—	2	—	—	2	5
23-8-77	—	—	2	2	—	1	2	—	—	3	5
24-8-75	—	—	1	1	—	—	5	—	—	5	6
7-9-76	—	—	—	—	—	—	3	—	—	3	3
10-9-76	—	—	5	5	—	—	4	—	—	4	9
10-9-77	—	—	4	4	—	—	5	—	—	5	9
13-9-75	—	—	4	4	—	—	—	—	—	—	4
14-9-73	—	—	3	3	—	—	3	—	—	3	6
19-9-76	—	—	1	1	—	—	4	—	—	4	5
25-9-76	—	—	4	4	—	—	2	—	—	2	6
25-9-77	—	—	1	1	—	—	2	—	—	2	3
28-9-75	—	—	2	2	—	—	2	—	—	2	4
29-9-71	—	—	1	1	—	—	2	—	—	2	3
2-10-76	—	—	2	2	—	—	2	—	—	2	4
3-10-71	—	—	3	3	—	—	—	—	—	—	3
8-10-77	—	—	3	3	—	—	1	—	—	1	4
9-10-76	—	—	1	1	—	—	3	—	—	3	4
11-10-75	—	—	—	—	—	—	7	—	—	7	7
12-10-75	—	—	1	1	—	—	—	—	—	—	1
14-10-75	—	—	1	1	—	—	—	—	—	—	1
16-10-71	—	—	2	2	—	—	2	—	—	2	4
18-10-75	—	—	2	2	—	—	—	—	—	—	2
18-10-76	—	—	2	2	—	—	3	—	—	3	5
23-10-76	—	—	1	1	—	—	3	—	—	3	4
23-10-77	—	—	2	2	—	—	2	—	—	2	4
28-10-73	—	—	1	1	—	—	1	—	—	1	2
30-10-76	—	—	3	3	—	—	6	—	—	6	9
6-11-71	—	—	1	1	—	—	—	—	—	—	1
7-11-76	—	—	—	—	—	—	2	—	—	2	2
10-11-73	—	—	1	1	—	—	1	—	—	1	2
12-11-77	—	—	9	9	—	—	10	—	—	10	19
13-11-76	—	—	4	4	—	—	1	—	—	1	5
15-11-75	—	—	2	2	—	—	—	—	—	—	2

1	2	3	4	5	6	7	8	9	10	11	12
18-11-73	—	—	3	3	—	—	3	—	—	3	6
20-11-76	—	—	5	5	—	—	1	—	—	1	6
22-11-75	—	—	1	1	—	—	3	—	—	3	4
23-11-75	—	—	2	2	—	—	—	—	—	—	2
26-11-77	—	—	7	7	—	—	16	—	—	16	23
27-11-76	—	—	4	4	—	—	1	—	—	1	5
1-12-73	—	—	3	3	—	—	1	—	—	1	4
4-12-77	—	—	5	5	—	—	3	—	—	3	8
5-12-75	—	—	—	—	—	—	1	—	—	1	1
5-12-76	—	—	2	2	—	—	3	—	—	3	5
8-12-73	—	—	3	3	—	—	—	—	—	—	3
10-12-77	—	—	2	2	—	—	1	—	—	1	3
11-12-76	—	—	6	6	—	—	4	—	—	4	10
11-12-77	—	—	3	3	—	—	—	—	—	—	3
12-12-76	—	—	8	8	—	—	3	—	—	3	11
13-12-77	—	—	9	9	—	—	3	—	—	3	12
15-12-75	—	—	1	1	—	—	1	—	—	1	2
15-12-77	—	—	1	1	—	—	1	—	—	1	2
16-12-77	—	—	4	4	—	—	6	—	—	6	10
18-12-76	—	—	1	1	—	—	1	—	—	1	2
18-12-77	—	—	8	8	—	—	6	—	—	6	14
23-12-73	—	—	1	1	—	—	—	—	—	—	1
23-12-76	—	—	3	3	—	—	—	—	—	—	3
24-12-76	—	—	2	2	—	—	1	—	—	1	3
27-12-76	—	—	2	2	—	—	—	4	—	4	6
28-12-76	—	—	1	1	—	—	—	—	—	—	1
29-12-71	—	—	2	2	—	—	—	2	—	2	4
31-12-76	—	—	5	5	—	—	—	13	—	13	18
31-12-77	—	—	4	4	—	—	—	1	—	1	5

TABLE 2
MONTHWISE COLLECTION OF THE SPECIMENS

Month	Males	Females	Total
January	16	67	83
February	22	55	77
March	21	51	72
April	39	99	138
May	61	73	134
June	17	27	44
July	17	43	60
September	25	27	52
August	13	22	35
October	24	30	54
November	39	38	77
December	76	55	131
Total	370	587	957

and the mammary nipples are visible only after the first lactation.

2. BREEDING HABITS

The examination of table 1 shows that pregnancies as evidenced by the occurrence of bulbous uterine cornua are present only from about the first week of January to about the fourth week of April. The one female collected on January 4 showed unmistakable sign of pregnancy since there was a swelling in both the uterine cornua. Between January 4 and January 12 progressively there was a greater proportion of females with bulbous uterine cornua among the specimens collected on each

date. All females collected between January 12 and April 4 had noticeably large conceptus in the uterine cornua and carried progressively advanced stages of development of the foetus.

Microscopic examination of the females revealed some interesting features. Some of the female specimens collected on November 12 had undergone copulation as evidenced by the fact that sperms were present in the uterus and the uterine end of the fallopian tubes. Their ovaries had follicles in the multilaminar condition, and one or two follicles showed the beginning of the formation of antral spaces. Sperms were present in the uterus and the uterine end of the fallopian tubes of all females collected on and after November 12 and up to December 27, thereby indicating that copulation had taken place in all the females. One female collected on December 27 had a four-celled egg in the uterus. Free early embryos in progressively advanced stages of cleavage were present in every female collected between December 27 and January 4.

These facts indicate that although copulation occurs as early as November 12, ovulation does not take place until about the last week of December (Gopalakrishna and Madhavan, 1978). Secondly, ovulation occurs in all the specimens within a sharply defined period in the last week of December and fertilization and pregnancy follow immediately.

Although every female collected during January, February and March was pregnant, and although progressively advanced stages of development of the embryos were present during the successive weeks after December 27 it was noticed that the size of the conceptus carried by different females collected on any given date during February to April varied. This indicates that the rate of embryonic development may not be the same in all the specimens.

The last batch of pregnant females could be collected on April 25 although pregnant females probably occur until May 3 as evidenced by the fact that newly delivered young ones were available until May 3. After this date there was not a single female which could be assigned to having delivered recently although vigorous efforts were made to collect specimens at frequent intervals. Evidently all females in the roost had delivered their young by May 3. Pregnancy was not found to occur in any other month of the year. The above facts show that *Scotophilus heathi* has an annual reproductive cycle confined to a sharply restricted period.

The first batch of postpartum mothers and newly born young ones was collected on April 4. The young ones weighed 5.5 to 6.0 g, and in each case the umbilical cord was still attached to the body, the eyelids were adherent and the body was devoid of hair. These characters taken along with the fact that the highest weight of the foetus was 5.0 g, indicates that they might have been born less than a day before. It was interesting to note that although all females undergo ovulation and become pregnant during the last week of December (and not a single non-pregnant female was collected after December 27 until April 4 during the six years when collections were made during these months) all deliveries in the colony do not occur at about the same time. After April 4, when the first batch of postpartum mothers were obtained in the year, progressively more females in a collection had delivered their young during the following days until April 25. It is very likely that a few deliveries occur after April 25 until May 3 as mentioned earlier. This fact is an additional evidence to indicate that the rate of embryonic development varies in the different specimens as otherwise all females should deliver within a

short span of time since all females become pregnant in a sharply defined period in the last week of December. Evidently the duration of pregnancy varies between 100 to 130 days, calculating the minimum period of gestation as 100 days from the first day when early cleavage stage of the egg was noticed (December 27) to the date on which the first delivered young are collected (April 4) and 130 days as being the maximum period as calculated until May 3, when the last deliveries probably occurred, and allowing a margin of a couple of days on either side.

The sucklings are carried by their mothers at their breasts while they are in the roost or when they are disturbed when they fly away with the young attached to the breast. The first batch of weaned free young ones was collected on May 1. Assuming that these were the young ones delivered in the first batch (that is around April 4) it is evident that the young are suckled for about 24 to 28 days allowing a margin of a couple of days. All the mothers in the colony are free of their young by the end of May. However, the females continue to be in lactation until the first week of August.

From the foregoing account of the breeding habits of *Scotophilus heathi* the annual life of the adult female of this species can be recognized into the following periods: (1) period of sexual quiescence from about the second week of August until the first week of November; (2) period of copulation from the second week of November until the last week of December; (3) ovulation and fertilization during the last week of December; (4) pregnancy from the last week of December until about the first week of May; (5) lactation from about the first week of April until about the first week of August.

On comparing the breeding habits of this

bat with those of other Indian bats, it is interesting to note that *Scotophilus heathi* resembles *Pipistrellus ceylonicus chrysothrix* (Gopalakrishna and Madhavan, 1971) in that the inseminated sperms remain viable and successfully fertilize the ova released several weeks later. It was earlier known that survival of inseminated spermatozoa is a characteristic feature present only in the bats living in cold and temperate climates (Gates, 1936; Folk, 1940; Wimsatt, 1942, 1944; Hiraiwa and Uchida, 1956). It is now evident that this phenomenon is also prevalent in several tropical bats (Medway, 1972; Gopalakrishna and Madhavan, 1978). *Scotophilus heathi* resembles most Indian bats in having a sharply restricted annual breeding cycle (Gopalakrishna, 1947, 1948, 1949, 1950; Ramakrishna, 1951; Ramaswamy, 1961; Madhavan, 1971; Gopalakrishna and Rao, 1977; Madhavan *et al.*, 1978; Gopalakrishna and Madhavan, 1978). Only a few Indian bats have been known to breed more than once a year (Gopalakrishna, 1954, 1955; Gopalakrishna *et al.*, 1975; Madhavan, 1978).

3. NUMBER OF YOUNG AND SYMMETRY OF THE FEMALE GENITALIA

Unquestionable indication of pregnancy as evidenced by the occurrence of bulbous uterine cornua was noticed in the females collected between January 4 and April 25. During this period altogether 245 pregnant females were collected. Out of these 219 had an embryo in each uterine cornu. There were 25 females having a single embryo each — 15 of these had the foetus in the right cornu and 10 in the left. One female carried two embryos in the right cornu of the uterus and the left had none. Examination of the ovary of the pregnant females revealed that a single corpus

luteum was present in each ovary in the specimens having a single foetus in each uterine cornu. In the case of the specimen which had two embryos in the right cornu the right ovary had two corpora lutea and none in the left. Evidently, the two sides of the genitalia are symmetrical morphologically and physiologically, and each side is equally functional during each reproductive cycle.

4. GROWTH AND MATURITY

The growth of the body of the young one is rapid during the early life and the young animals weigh almost as much as the adults when they are about 5 months of age so that young ones cannot be distinguished from the adults on the basis of the size of the body after this age. Until the middle of September, that is up to the age of 4 to 5 months, the young ones of the year can be distinguished from the adults by their having dark brown fur on the back and grey fur on the belly. Older adults have invariably bright yellow fur on the ventral side in both sexes. Sexual maturity is attained by specimens of both sexes at the body weight of about 28 g. The young ones are attached to the mother's breasts for about 24 to 28 days. The highest weight of an attached young one was 23 g and the lowest weight of a naturally weaned free young one was 24 g. It is evident that the young ones become free from their mothers when they reach about this weight. The young ones grow rapidly and increase in their weight by well over four times (from 5.5 g to 24.0 g) during the sucking period. Several juvenile specimens were collected from the first week of June until the middle of September. Since the examination of the stomach contents of these animals revealed the absence of curdled milk it is evident that the juveniles

do not visit the lactating females after May. The growth of the young one is not rapid through the months of August and September, but they gain weight during October, November and December. Hence, October onwards it is not possible to distinguish the animals born in the year from the adults on the basis of the size of the body. However, in the case of females the animals of the year can be recognized as they do not have well-developed nipples. Microscopic examination of the testes of specimens collected during October, November and December revealed that all the males exhibited spermatogenetic activity. All the females become pregnant during the last week of December. This indicates that sexual maturity is attained in both sexes in the year of their birth and when they are 5 to 6 months of age.

5. SEX RATIO

Out of a total of 957 specimens collected at random and at frequent intervals for over 6 years, there were 370 males and 587 females giving a sex ratio of 630 males per 1000 females. This should reflect the natural sex ratio in this species in the total population since there is no segregation on the basis of sex, age or season in this species. There were equal number of males and females among 86 young ones found attached to their mother's breasts. Evidently, there is a balanced sex ratio during early juvenile life, and the difference in the proportion of males to females in the adult period is due to larger mortality of the males during the adolescent period.

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