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Nestling Sounds of the Plantain Squirrel (Sciuridae: *Callosciurus notatus*)

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Abstract A hand-reared nestling of *Callosciurus notatus* elicited five types of vocalization. The chirp sound began to be used in the early stage of development before the eyes opened and apparently remained throughout life. It was emitted to appease conspecific individuals. The coo sound was also observed as the nestling sought contact. The peep sound elicited when the nestling was left alone had several acoustic characteristics common to other sciurid species. The tick sound heard before the weaning period was so faint that it reached only a short distance. It is suggested that the sound may prompt the nearby mother to perform nursing and other care behavior. The chuckle sound first produced at 5 weeks of age after the eyes had opened was solely used as an alaram signal.

Key words: Vocalization, *Callosciurus notatus*, sciurids, nestling.

Nestling sounds have been reported in some species of tree squirrel distributed in temperate regions (Eibl-Eibesfeldt, 1951; Horwich, 1972; Farentions, 1974; Lishak, 1982). Emmons (1978) classified the sounds of adult and young African tree squirrels into six categories based on sound structures and functional meanings, and compared them with those of temperate species.

Callosciurus species, tree squirrels living in Southeast Asia, have various types of vocalization and frequently use them in the field. As for *C. notatus* Boddaert, only the adult vocalizations have been reported (Tamura, 1992; Tamura and Yong, 1992). The purposes of the present study are to describe the nestling sounds of *C. notatus* with reference to some aspects of adult vocalizations, and to compare the sounds with those of other tree squirrels.

Materials and methods

One female neonate of *C. notatus* was found on the forest floor close to the study station in Ulu Gombak, Selangor Darul Ehsan, Malaysia, on 8 July 1990. The peeping neonate was apparently intact. The body weight was 52.8 g and the eyes were still closed.

The neonate was hand-reared at the study station. It was fed with powdered milk for human babies basically for the first two weeks of rearing, and mashed banana and papaya were added after the 4th day. Both eyes opened on 10 July, and the eruption of upper and lower teeth was completed by 13 July. The body weight increased to 180.0 g the 80th day after eye-opening, and reached nearly 60% of the mean body weight of mature females trapped in the area (Fig. 1). The squirrel was free to wander about, and began to explore the forest after five weeks. However, it always came back to the rearer for the night until 30 September 1990, 82 days after eye-opening, when the rearer left the study station.

Recording of sounds was conducted on five different days; 9 July (one day before eye-opening), 11 July (one day after eye-opening), 25 July (two weeks after eye-opening), 31 July (three weeks after eye-opening), and 15

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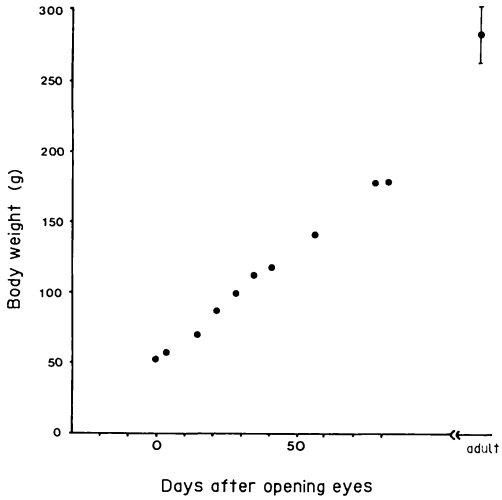

Fig. 1. The body weight change of female nestling of the plantain squirrel during the development. The mean and SD of the adult body weight was calculated for 13 mature females captured with live-traps.

August (five weeks after eye-opening). Sounds of mature individuals were also collected in the field.

Sound recording was made using a cassette recorder (SONY TC-D5M) with a directional condenser microphone (Victor MU-510). The recording distance of nestling sounds was 0.5–2.0 m and those of mature individuals 7.0–15.0 m. In the laboratory, recordings were analyzed by a KAY DSP Sonagraph Model 5500, covering a frequency range of 0 to 32,000 Hz.

Results and discussion

The sound characteristics of each sound type are summarized in Table 1.

1. Chirp

The chirp sound was heard throughout the recording sessions during development. However, the characteristics of the sound changed as the nestling grew (Table 1, Fig. 2). The number of peaks in the wave pattern increased from almost two to ten, and the note duration (Dr) also lengthened. The frequency modulation (Md; the difference between Fl and Fh) decreased with development. The sound of the neonate was just too faint to hear even from 1.0 m. The intensity gradually increased after two weeks, and for mature individuals the sound became audible approximately 10.0 m away from the caller (Tamura, 1992).

Changes in the sound characteristics appeared to parallel behavioral development. For the first two days after collection, the nestling elicited the chirp sound whenever the rearer went away, but stopped calling when it was touched and groomed by hand. This may suggest that the chirp sound is triggered by the uneasy experience of being left alone. Three days later, however, the nestling hardly made the same reaction any more. It became silent and seldom produced the chirp sound. Two weeks after eye-opening, it became active and frequently elicited the chirp sound with other types of vocalization. For example, when the rearer was having a meal, the nestling approached her eliciting the chirp sound.

Mature individuals also produced the chirp sound. Males produced it when they pursued estrous females to mate (Tamura, 1992). Mothers also used it to call to isolated offsprings in the forest.

As the behavioral context suggests, the chirp sound seems to express friendly and non-aggerssive intentions, seek contacts with, and appease conspecific individuals (Eibl-Eibesfeldt, 1951; Emmons, 1978).

The acoustic features of the chirp sound of *C. notatus* were fairly different from those of other squirrels such as *Sciurus carolinensis* (Lishak, 1982), *Protoxerus stangeri* and African squirrels (Emmons, 1978). Nevertheless, it appears to share similar functions among these species.

2. Coo

The coo sound was first noticed as a single note on 8 July, the day of collection, and was most frequently used three weeks after eye-opening (Table 1, Fig. 3a–e). The maximum audible distance was approximately 5.0 m. The sound was emitted as a single note at first, but the note was repeated four or more times in a sequence three weeks after eye-

Table 1. Sound characteristics of the plantain squirrel during the development. Abbreviations; Dr: note duration, Fh: the highest fundamental frequency, Fl: the lowest fundamental frequency, Md: modulation in frequency, INI: inter-note interval. See also Fig. 2a, 3af, 4af. Numerals indicate mean±SD, and those in parentheses sample size.

Sound type		A hand-reared nestling					Wild mature individuals
		1 day before opening eyes	1 day after opening eyes	2 weeks after opening eyes	3 weeks after opening eyes	5 weeks after opening eyes	
Chirp	Dr (msec)	79±20 (6)	97±20 (13)	89±20 (13)	105±20 (14)		198±50 (32)
	INI (msec)	387±30 (3)	373±110 (8)	431±10 (9)	390±80 (12)		423±80 (19)
	Fh (KHz)	9.04±0.43 (6)	9.72±0.42 (13)	9.41±0.38 (13)	9.54±0.28 (14)		8.61±0.43 (28)
	Fl (KHz)	4.98±0.66 (6)	6.32±0.97 (13)	7.44±0.48 (13)	7.55±0.35 (14)		6.69±0.78 (28)
	Md (KHz)	4.05±0.29 (6)	3.49±0.90 (13)	1.97±0.35 (13)	1990±367 (14)		1.91±0.48 (28)
	No. of peaks	2.33±0.80 (6)	3.14±0.83 (11)	4.15±1.06 (13)	5.07±1.33 (14)		9.94±1.18 (8)
Coo	Dr (msec)	79±40 (2)	56 (1)		59±20 (18)		
	Fh (KHz)	2.14±0.14 (2)	1.71 (1)		1.43±0.17 (18)		
	Fl (KHz)	1.14±0 (2)	0.86 (1)		0.62±0.10 (18)		
Peep	Dr (msec)	55±20 (7)			68±20 (8)		168±50 (28)
	Fh (KHz)	5.05±0.31 (7)			6.09±0.96 (8)		11.07±0.60 (26)
	Fl (KHz)	2.33±0.36 (7)			3.13±0.90 (8)		4.51±1.21 (26)
Tick T1	Dr (msec)	13±2 (5)		20±7 (5)			
	Fh (KHz)	3.43±0.63 (5)		4.29±0.92 (5)			
	Fl (KHz)	2.26±0.77 (5)		2.59±0.46 (5)			
T2	Dr (msec)	15±2 (4)					
	Fh (KHz)	1.94±0.51 (4)					
	Fl (KHz)	0.69±0.23 (4)					
Chuckle	Dr (msec)					19±5 (5)	26±8 (16)
	Fh (KHz)					4.00±0.27 (5)	4.39±0.29 (16)
	Fl (KHz)					2.18±0.24 (5)	2.48±0.37 (16)

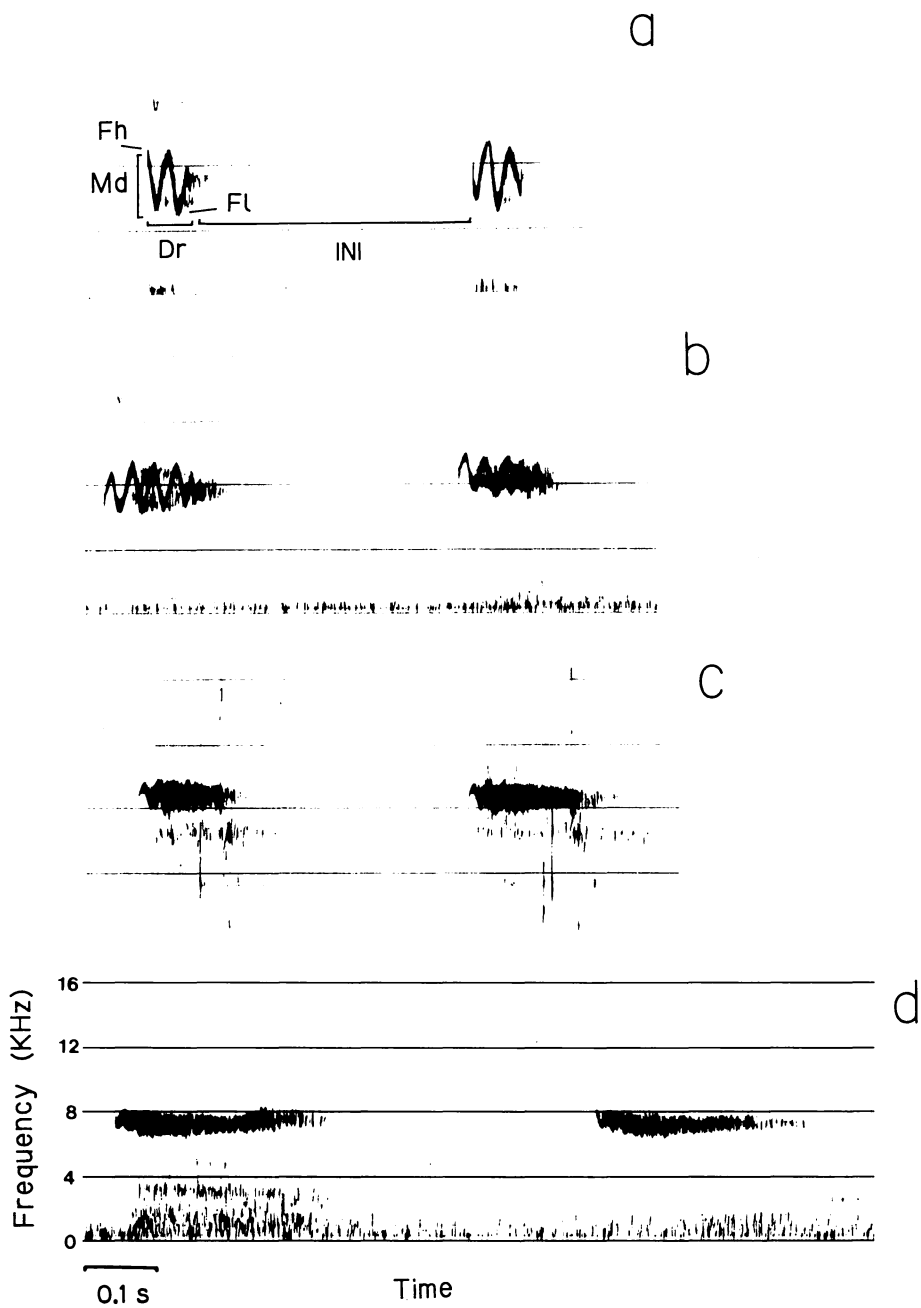

Fig. 2. Sonagrams of the chirp sound recorded from the nestling at 1 day before opening eyes (a), 1 day after opening eyes (b), and 2 weeks after opening eyes (c), and also a mature male call during mating (d). For abbreviations, see Table 1. All graphs are the same scales as (d).

opening. The sound frequency of both Fh and Fl became lower with development. This may be explained partly by the increase in body size, as reported for frogs (Ryan, 1980).

The coo sound tended to accompany the chirp sound when the rearer was taking a meal. Emmons (1978) classifired the coo sound in the same category as the chirp sound, based on their functional meanings. In fact, some African squirrels possess two

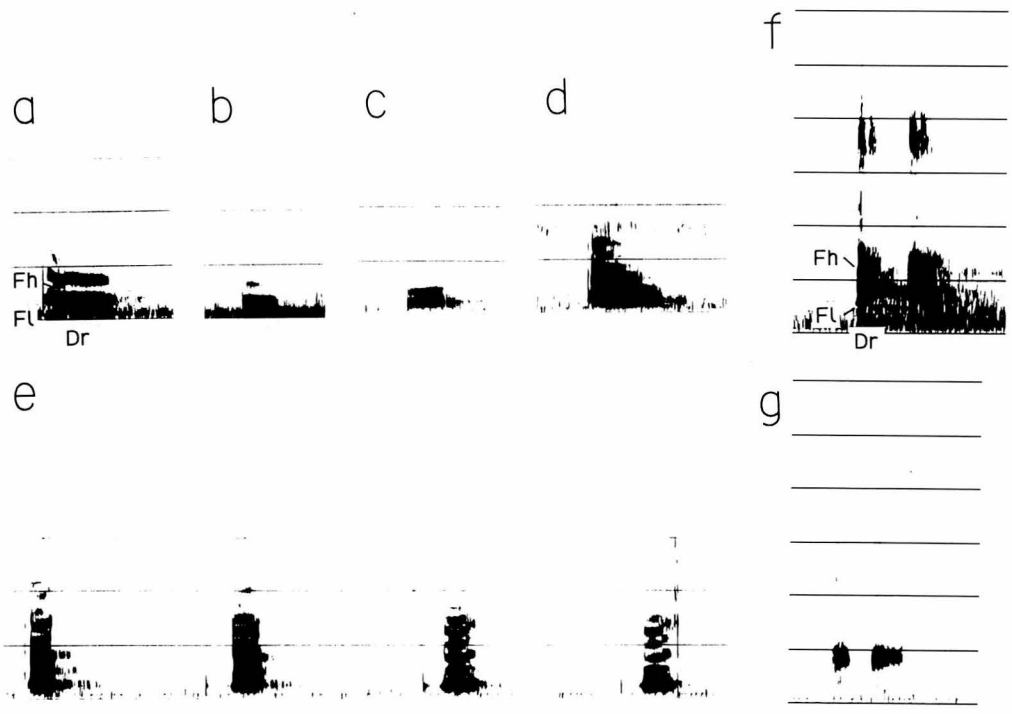

Fig. 3. Sonagrams of the coo sound recorded from the nestling at 1 day before opening eyes (a)–(b), 1 day after opening eyes (c), 3 weeks after opening eyes (d)–(e), and the chuckle sounds recorded from the nestling at 5 weeks after opening eyes (f), and that of a captured mature female (g). For abbreviations, see Table 1. All graphs are the same scales as Fig. 2d.

sound types for the situation of contact-seeking and use them in accordance with the degree of excitement.

3. Peep

The peep sound was frequently produced until the third week after eye-opening (Table 1, Fig. 4a–d). The sound frequency became higher, and its duration longer, with development. The sound was also characterized by a pure tonal structure, gradual onset and ending, single repetition at long intervals, and high frequency. Although the call was lond enough to hear 10.0 m away, these four characteristics are speculated to make it difficult to localize the caller's position (Marler, 1955). It can be an adaptation to protect vulnerable nestlings from predators. A similar structure has also been observed in other tree squirrels (Horwich, 1972; Farentinos, 1974; Emmons, 1978).

It was from the peep sound that the rearer discovered the nestling on the forest floor. It was difficult to record the sound, since the nestling called while the rearer was absent and stopped calling as the rearer approached. According to Emmons (1978), this sound may be typical of nestlings, and may induce their mother to search for and retrieve them immediately.

In the field, mature individuals emitted peep sounds when they encountered snakes (Fig. 4e). Similar phenomena have been reported in other *Callosciurus* species (Tamura, 1989; Tamura and Yong, 1992). Upon hearing this sound, neighboring conspecific individuals assembled around the caller and mobbed in a group.

4. Tick

The tick sound was produced until the nestling was weaned two weeks after eye-opening (Table 1, Fig. 4f–1). It was too faint to hear beyond 0.3 m. It would be classified

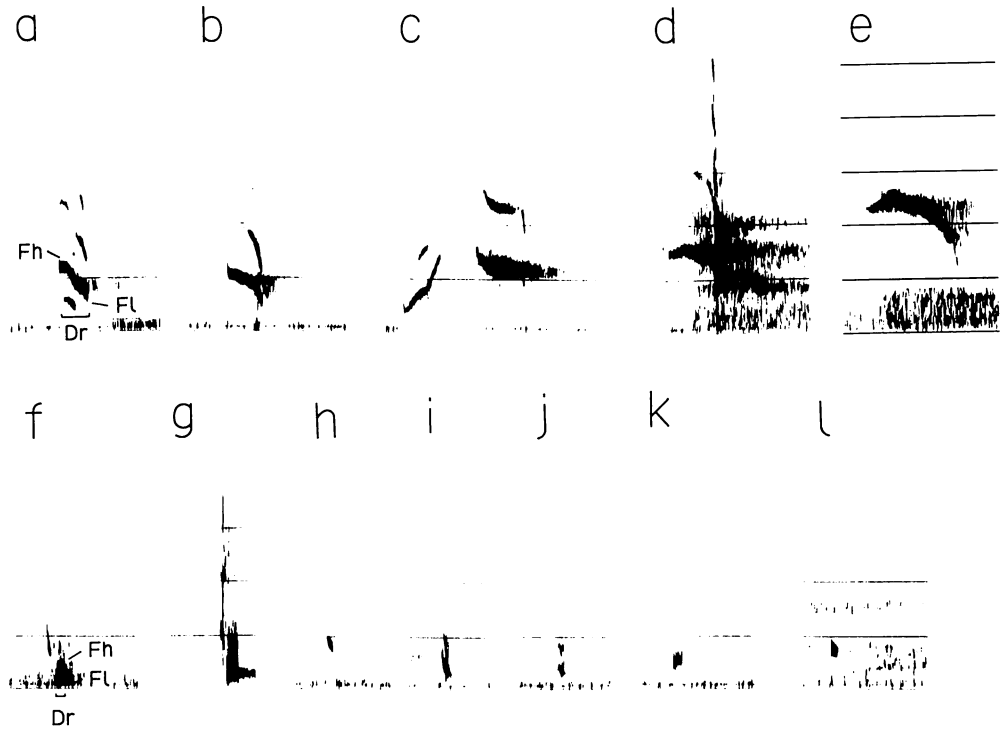

Fig. 4. Sonagrams of the peep sounds recorded from the nestling at 1 day before opening eyes (a)–(c), and 3 weeks after opening eyes (d), and also from a mature female during mobbing (e), and those of the tick sounds recorded from the nestling at 1 day before opening eyes (f)–(h), 2 weeks after opening eyes (i)–(l). (f)–(g) were the T2 type and (h)–(l) T1. For abbreviations, see Tabel 1. All graphs are the same scales as Fig. 2d.

into two types based on its frequency (T1: Fig. 4f–g, and T2: Fig. 4h–1), although no differences in behavioral context were detected.

The nestling elicited both types of ticks when the rearer stayed and touched her. As Emmons (1978) mentioned, tick calls may stimulate maternal behavior such as nursing and grooming.

5. Chuckle

During the study period, the nestling produced the chuckle sound five weeks after eye-opening (Table 1, Fig. 3f–g). It was elicited when the nestling looked down to the ground, where a skink was foraging on fallen leaves. This sound was also used by mature individuals when captured in a trap, or was alerted as a sign of predators. The nestling chuckle sound did not differ from that of mature individuals, and was classified as an alarm call. There are several types of alarm call observed in *Callosciurus* species (Tamura and Yong, 1992). However, only one kind was used by *C. notatus* nestling.

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バナナリス (*Callosciurus notatus*) の幼獣の音声

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マレーシアの樹上性リス *Callosciurus notataus* の幼獣を飼育し音声を記録した．その結果，開眼以後5週令までの期間に5種類の音声が識別された．(1) チャープは幼獣期には餌や接触を求める際に発せられたが，成獣では配偶行動においてオスによって発せられたり，メスが子を呼び寄せるときなどに使われた．(2) クーは幼獣期にチャープとともに用いられたが，成獣では聞かれなかった．(3) ピープは5種類の音声のなかではもっとも大きい声で，緊急時に母親を呼び寄せるために発せられた．この音声の特徴は他の種類の樹上性リスのそれと共通していた．(4) テイックはおそらく巣内にいる母親にのみ到達する程度の小さい声で，授乳を催促するなどの機能をもっていると思われる．離乳とともに聞かれなくなった．(5) チャックルは開眼後5週令ではじめて発せられた．成獣では捕食者のタイプごとに異なる音声が用いられるが，幼獣期に発せられたのはチャックだけであった．