Proc. Indian Acad. Sci. (Anim. Sci.), Vol. 98, No. 2, March 1989, pp. 89–93.

Seasonal changes in the timing of hopping and feeding activities of a tropical bird (*Estrilda amandava*) under natural photoperiod

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MS receiyed 16 July 1988; revised 26 December 1988

Abstract. The timings of onset and end of hopping and feeding activities of the bird *Estrilda amandava*, were studied under natural light-dark cycles and they are found to keep pace with the timings of sunrise and sunset. The onsets of hopping and feeding occurred at different timings of twilight and they vary over the seasons. The phase angle difference (ψ) of hopping always shows a considerable phase lead relative to feeding which also varies over the seasons and thus suggests that there may be two endogenous oscillators, one responsible for hopping and the other for feeding.

Keywords. *Estrilda amandava*; hopping; feeding; photoperiod; phase angle difference.

1. Introduction

Many bodily functions of organisms oscillate rhythmically and keep pace with the geophysical temporal order (Bünning 1973, 1982). In higher vertebrates, the main entraining agent or 'zeitgeber' is the natural light-dark cycle (Aschoff *et al* 1982). In animals, locomotor activity is best suited to demonstrate the seasonal changes in temporal relationship between activity cycles and environmental cycles (Daan and Aschoff 1975). The timings of onset and end of activity can be easily used as reference points for their rhythms (Chandrashekaran *et al* 1983).

In recent years, many investigators have made systematic field studies on seasonal trends in the timings of activity in birds and mammals (Daan and Aschoff 1975; Kenagy 1976; Pohl and West 1976). Several studies specifically illustrate the temporal disparity between feeding and activity patterns under various photoperiods (Gänshirt *et al* 1984). In the present study, we made observations on hopping and feeding activities of the tropical bird red-headed munia, (*Estrilda amandava*) under natural photoperiod and we present evidence that these birds exhibit marked changes in the temporal relationships between hopping and feeding activities in relation to the environmental parameters.

2. Materials and methods

Red-headed munia birds (*E. amandava*) were caught (n = 50–75) near the University campus and kept in the outdoor aviary (5·8 × 2·4 × 2·4 m). They were fed with millets and grains (*ad lib*) . Visual observations on the timings of onset and end of hopping and feeding were made for 10 months (from July–April). The time of hopping and feeding of the first bird was considered as the index of onset of activity

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and onset of feeding of the flock respectively. Similarly, the time at which the last bird roosted was considered as the end of activity of the flock and the feeding time of the last bird was considered as the end of feeding. Sunrise and sunset times were obtained from the tables of the Indian Ephemeris Nautical Almanac published by the Director of Observatories, Calcutta and were adjusted for longitude, latitude and Indian Standard Time (IST). Seasonal variations of timings of onset and end of hopping and feeding were used to calculate the phase angle difference (ψ) and activity time following the method of Daan and Aschoff (1975) and Kenagy (1976).

The phase angle differences (ψ_o, ψ_e, ψ_m) of hopping and feeding are calculated as follows:

ψ onset (ψ_o) = Time difference between sunrise and onset of activity.
ψ end (ψ_e) = Time difference between sunset and end of activity.
ψ midpoint (ψ_m) = $\frac{1}{2}(\psi_{onset} + \psi_{end})$.

3. Results

The duration of activity period was measured as the time elapsed between the first hopping and the last roosting of the birds. Similarly, the duration of feeding period of the flock was measured as the time elapsed between the onset and end of feeding activities of the flock. The timings of onset and end of activity and feeding systematically changed and paralleled the timings of sunrise and sunset respectively (figure 1). The duration of activity was always longer than the photoperiods and the duration of feeding was always shorter than the photoperiods. The duration of activity and feeding (figure 2) are linearly correlated with the duration of daylength ($r = 0.85$ for activity period and $r = 0.9$ for feeding period).

The temporal relationship between the biological and environmental cycles can be expressed by the phase angle difference (ψ) of the onset (ψ_o) and end (ψ_e) of activity (Daan and Aschoff 1975). The theory of oscillation suggests that day active animals have largest ψ_o and smallest ψ_e during shorter photoperiods; smallest ψ_o and largest ψ_e during longer photoperiods. The birds have their largest and smallest ψ_o of hopping and feeding during shorter and longer photoperiods respectively. The largest ψ_e of hopping and smallest ψ_e of hopping and feeding occurred during longer and shorter photoperiods respectively concurring with the theory of oscillation. However the largest ψ_e of feeding did not occur during longer photoperiods (March–July) but during January (figure 3).

According to Aschoff (1965, 1969) a third measure of phase angle difference between the activity rhythm and the entraining light-dark cycles is ψ-midpoint (ψ_m) i.e. the time interval between the midpoint of activity and midpoint of daytime. The seasonal course of ψ_m of activity showed relatively lesser variations compared to ψ_o and ψ_e. The birds have less negative or more positive ψ_m values during longer photoperiods and more negative or less positive ψ_m values during shorter photoperiods. Similar is the case with the ψ_m of feeding activity (figure 3).

4. Discussion

The hypothesis that the daily activity of an animal depends upon an endogenous timer and re-setting by environmental cues is not peculiar to birds and our data

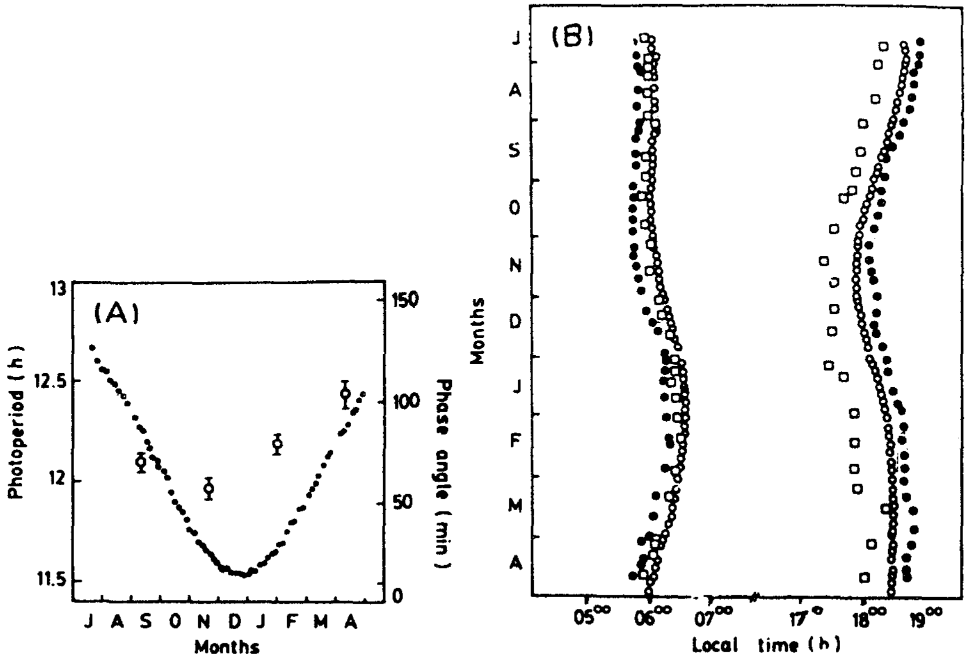

Figure 1. A. Photoperiod over the seasons. The time difference (phase angle) between hopping and feeding onsets over the seasons (Mean ± SD) are plotted. Note that during longer photoperiods the difference is larger and during shorter photoperiods the difference is lesser. **B.** Timings of onset and end of hopping and feeding under natural photoperiod. (○), Timings of sunrise and sunset; (●), onset and end of hopping; (□), onset and end of feeding.

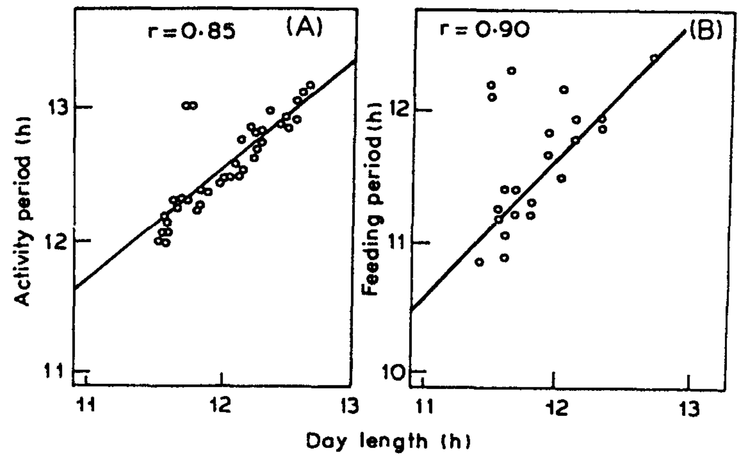

Figure 2. Linear regressions of duration of hopping and feeding with daylength.

merely broaden the comparative base of a well-grounded theory formulated by several authors (Bruce 1960; Pittendrigh 1960; Aschoff 1963). The comparison of activity time (α) as a linear function of daylength (figure 2) shows that α follows the seasonal variation rather closely (Kenagy 1976; Pohl and West 1976; Erkert 1978;

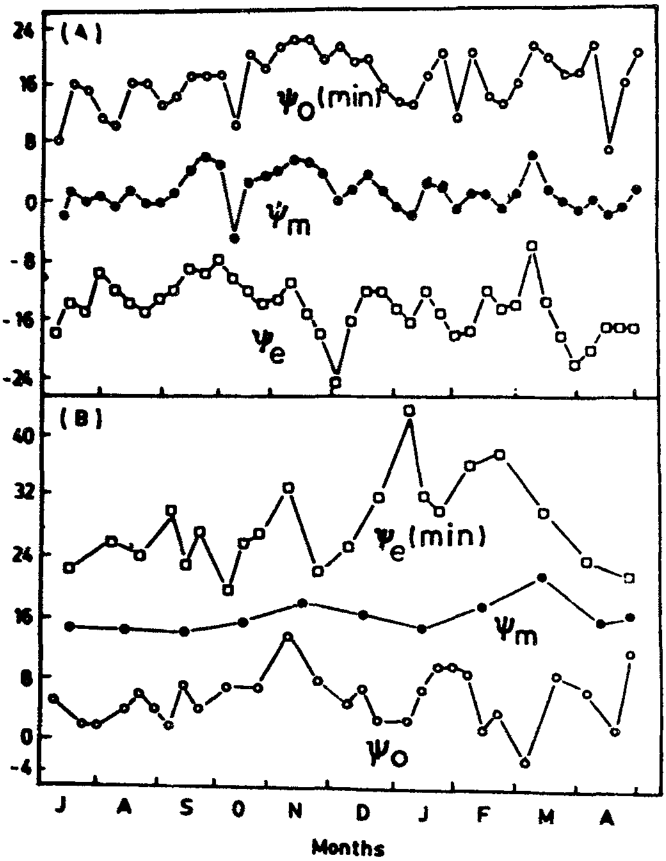

Figure 3. Seasonal changes in the phase angle differences (min) (ψ_o, ψ_e, ψ_m) of hopping (A) and feeding (B) activities of the bird flock over the seasons.

Georgii 1981). In temperate regions α follows the seasonal variations of daylength only to a limited extent. For example, in day-active birds an S-curved relationship was reported by Daan and Aschoff (1975). The activity time (duration of activity) on days shorter than about 5 h and days longer than 19 h is independent of daylength. In Madurai (9°59′N 78° 10′ E) the daylength does not vary much (0·26 min/day) and hence an S-shaped relationship could not be obtained.

The feeding time also shows a linear variation with daylength (figure 2). The time difference (phase angle) between ψ_o of hopping and ψ_o of feeding is lesser (59 min) during shorter daylengths and larger (102 min) during longer daylengths. The seasonal variations of ψ_o and ψ_e of hopping and feeding tend to exhibit an approximate mirror image (figure 3). This phenomenon of mirror imaging might have arisen through the events of light intensity variations during onset and end of activity over the seasons (Daan and Aschoff 1975).

Gänshirt *et al* (1984) reported that the hopping activity always had a phase lead relative to feeding in starlings (*Sturnus vulgaris*). In our birds too, the onset of hopping always had a phase lead over onset of feeding and the time difference is lesser (59 min) during shorter daylengths and larger (102 min) during longer daylengths similar to *S. vulgaris* (figure 1) (Gänshirt *et al* 1984). Such temporal disparity between activity and feeding might suggest that there may however, be two endogenous oscillators, one responsible for hopping and another one for feeding as claimed by Gänshirt *et al* (1984). But it is desirable to conduct experiments under controlled laboratory conditions (under dim LL or DD) to find out whether hopping and feeding are controlled by two separate endogenous oscillators in this tropical bird.

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