

OVARIAN CYCLE IN THE HOUSE GECKO, *HEMIDACTYLUS FRENATUS*, IN TAIWAN WITH REFERENCE TO FOOD STRESS IN WINTER

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Jun-Yi Lin and Hsien-Yu Cheng (1984) Ovarian cycle of the house gecko, *Hemidactylus frenatus*, in Taiwan, with reference to food stress in winter. *Bull. Inst. Zool., Academia Sinica* 23(1): 21-28. The female *Hemidactylus frenatus* Dumeril and Bibron in Taiwan has a definite breeding season from late March to September, though it appears to have reproductive potential throughout the year. Females reproduce in synchrony with the males.

Minimum adult female snout-vent (SV) length is 44 mm. Most newly hatched individuals (SV-length less than 25 mm) occur from mid-June to early November. Most of these hatchlings will mature in the following spring or summer. At most, two clutches are possible in a breeding season.

Food stress does occur and the nutrient state of the geckos are low in winter. However, fat reserves in fat bodies and tails occur mainly in winter, and appear to be used for the first clutch. The food stress in winter as a proximate factor plays an important part in determining the reproductive pattern of the species in Taiwan.

An organism can be conveniently viewed as a simple input-output system, with its foraging tactics providing as input of materials and energy which are expended on growth, maintenance and reproduction (Pianka, 1976; Van Devender, 1978). Lipid storage and utilization system, growth patterns and conditions could be used to understand the interactions between reproductive patterns, foraging tactics and growth patterns (Ballinger, 1977; Cheng and Lin, 1978; Derickson, 1976a; Hahn and Tinkle, 1965; Jameson, 1974; Licht, 1974; Martin, 1973, 1977; Mayhew, 1966a, b; Medica and Turner, 1976; Vinegar, 1975; Telford, 1970). These authors showed that the energy availability (food availability) and energy allocations are important bases for developing comprehensive hypotheses about

factors influencing lizard life histories.

Hemidactylus frenatus Dumeril and Bibron is a tropical and subtropical gecko, widely distributed in southeast Asia, Indochina, the East Indies, Africa, Madagascar, Oceanic islands and even Mexico and Australia (Pope, 1935; Grzimek *et al.*, 1972). Intraspecific reproductive studies on *H. frenatus* in different areas could result in a general elucidation of the evolutionary strategies in diverse environments. However, only two reproductive studies on *H. frenatus* have so far been made (Church, 1962; Cheng and Lin, 1977).

Church (1962) found that *H. frenatus* in Java has a continuous reproductive pattern. However, the male *H. frenatus* in Taiwan has been shown to confine its reproduction mainly to the spring and summer, though potentially it can reproduce throughout the

year (Cheng and Lin, 1977). This investigation presents the ovarian, the liver, the fat body and the tail weight cycles of female *H. frenatus*, and examines the relationship of food availability (food stress) and nutrient state to reproduction as an explanation for the ostensibly cyclical reproduction in the male and the female *H. frenatus*.

MATERIALS AND METHODS

Samples were collected at approximately fortnightly intervals from October 1975 to April 1977. Data from male samples collected during this same period have been reported and analyzed elsewhere (Cheng and Lin, 1977, 1978).

All specimens were collected from the campus of Tunghai University, Taichung, Taiwan (24° 10' N; 180 meters above the sea level), and etherized within three hours after capture. Their weight and snout-vent length (SV-length) were measured to the nearest 0.01 g and 0.1 mm respectively. Tails, livers and abdominal fat bodies were then removed and weighed to the nearest 0.1 mg. The stomach contents were removed and weighed to the nearest 1 mg. Follicles, oviducal eggs, and corpora lutea were counted and measured to the nearest 0.1 mm. Females were classified as reproductive when they contained either oviducal eggs or yolked ovarian follicles greater than 2.5 mm in diameter.

Proportionate liver weights and proportionate tail weights were determined by dividing the weight of the liver and the tail respectively by the body weight of the gecko without tail. In contrast to the liver weight, the weight of the fat body does not appear to have a high correlation with body weight in a given month. Thus the absolute fat body weights were used in our analyses. Tails with incomplete regeneration were not included in the analyses.

Four categories of stomach content weight—below 20 mg, between 20 mg and 60 mg, between 60 mg and 100 mg, and above 100 mg—were used to analyze nutrient intake of the

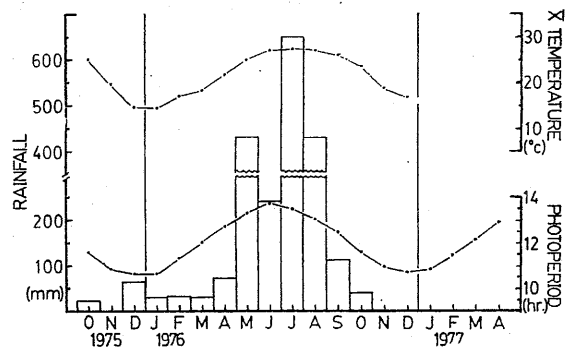


Fig. 1. Meteorological data for Taichung City during the study period.

geckos. The nutrient state was analyzed by computing the regression equation of body weight on SV-length for spring, summer and winter.

The meteorological data of the Taichung city (9 km from Tunghai Campus; 83.8 m above sea level) obtained from the Central Weather Bureau, Taipei, are given in Fig. 1. Plus and minus one standard error is used in all statistical analyses.

RESULTS

Adult *H. frenatus* were found to be active throughout the year. However, they were more or less inactive in winter. On cold nights, they usually retreated to crevices around the light fixtures and only their snouts could be seen.

Reproduction

The smallest mature female in the samples had an SV-length of 44.0 mm. All females greater than this length were considered adults. The time to reach maturity size was estimated to be about six to eight months after hatching.

The average of monthly mean SV-length for adult females was 51.0 mm (range 49.6–53.1 mm), and the average of monthly mean weights was 2.73 g (range 2.33–3.05 g). The largest female individual had an SV-length of 61.0 mm and weighed 4.06 g.

Changes in the monthly percentage of fecund females indicated a distinct reproductive pattern (Fig. 2). The percentage of fecund

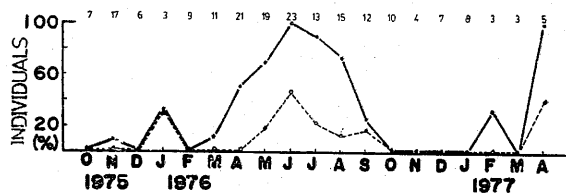


Fig. 2. Seasonal changes in the reproductive state of adult female *Hemidactylus frenatus*. Solid lines show the percentage of each sample containing yolked follicles, oviducal eggs or both. Dotted lines show the percentage of each sample containing oviducal eggs only. Number on the top is sample size for each month.

females began to increase from March 1976 and reached a peak in June when all individuals were in a reproductive state. Thereafter a steady decline began and no reproductive females were found in October. No significant increase in percentage of fecund females was observed between October and the following March in both years. The diameters of their pearl-like follicles ranged from 1.0 to 1.8 mm. However, one individual with oviducal eggs was observed in January 1976 and one individual with yolked follicles (size 5.0×4.6 mm) was observed in February 1977. Changes in the monthly percentages of females with oviducal eggs is also presented (Fig. 2) and shows an essentially similar pattern. Females with oviducal eggs were observed from May, indicating that vitellogenesis took about two months to complete.

At most, two clutches were produced in 1976. Only in the month of June, all females contained both yolked follicles and oviducal eggs, or both yolked follicles and corpora lutea, suggesting that June was the transitional month from the first clutch to the second. As September was the last month of the reproductive season in which 67% of fecund females contained oviducal eggs, we can fairly assume that the second clutch was laid between June and September.

Lengths and weights of oviducal eggs

varied from 7.0 mm to 9.8 mm and 101.2 mg to 330.0 mg. The size of the largest yolked follicle was 7.3 mm in diameter and 103.4 mg in weight. This follicle was observed to be just ovulated in body cavity.

Only in June, females with oviducal eggs more than 7.8 mm in diameter had yolked follicles at the same time, and during other months of the reproductive season, some females, which contained oviducal eggs larger than 8.0 mm (24% gravid females; largest 9.5 mm), had however, no yolked follicles. This suggests that there are individual differences in reproductive rate during the breeding season.

Copulation was observed mainly in the spring and summer. We caught one female in copulation on July 7th, 1976. This female possessed two yolked follicles, measuring 5.3–5.4 mm in diameter.

Amount of food in the stomach

Monthly distributions of the food weights in the stomach of male and female geckos showed that greater intake of food (category 2) occurred mainly from March to September (Table 1 and 2). Apparently as a result of the scarcity of available food in the winters, no individuals were able to accumulate food in the stomach of more than 60 mg.

Nutrient state

Regression analyses of body weight on SV-length were used as an index of the nutrient state in the geckos. The regression lines for each season and sex indicated a significant linear relationships. In both years, the regression lines of the males and females in winter were below those in spring and summer, indicating that the nutrient state of males and females in winter was not as satisfactory as in spring and summer (Fig. 3 and 4). In other words, at a given SV-length, the body weights of males and females in winter were lower than those in spring and summer. Apparently, this was due to the scarcity of available food in winter as indicated in Table 1 and 2.

TABLE 1
Stomach content weights of female geckos

Categories of stomach content weights (mg)	1975												1976												1977		
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	% of stomachs in each category									
0-20	73.7	20	33	56	22	19	13	14	39	20	33	40	25	60	100	100	0										
20-60	27	80	67	44	45	44	73	46	31	47	33	60	75	40	0	0	33										
60-100	0	0	0	0	22	31	14	23	15	13	25	0	0	0	0	0	33										
100-	0	0	0	0	11	6	0	18	8	20	8	0	0	0	0	0	33										
Sample size (n)	11	5	3	9	9	16	15	22	13	15	12	10	4	5	8	3	3										

TABLE 2
Stomach content weights of male geckos

Categories of stomach content weights (mg)	1975			1976												1977			
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
	% of stomachs in each category																		
0- 20	33	57	60	100	82	18	17	35	18	25	22	11	20	100	100	75	40	17	0
20- 60	67	43	40	0	18	45	33	35	45	31	78	33	40	0	0	25	40	0	33
60-100	0	0	0	0	0	18	25	29	18	25	0	44	10	0	0	0	0	33	67
100-308	0	0	0	0	0	18	25	0	18	19	0	11	30	0	0	0	20*	50	0
Sample size (n)	3	14	5	5	11	11	12	17	11	16	9	9	10	2	3	4	5	6	3

* This stomach only contains a tail of the gecko.

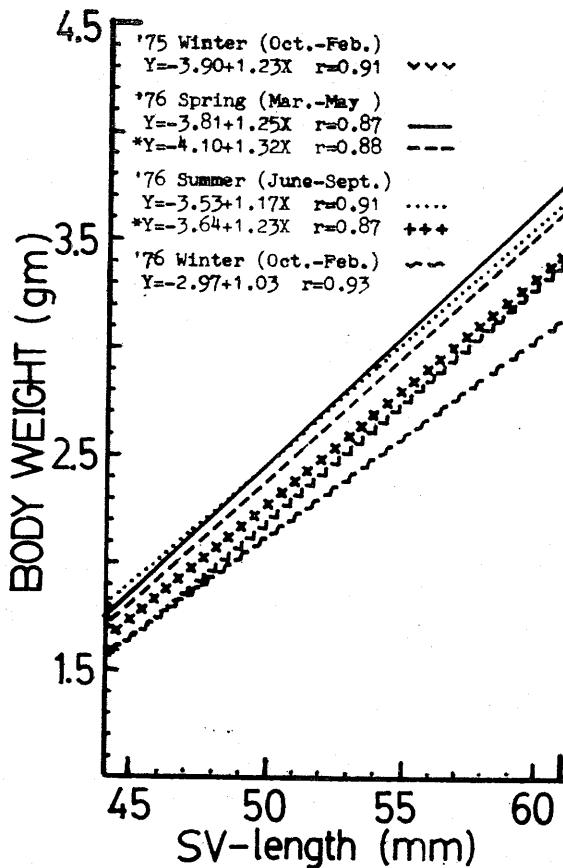


Fig. 3. Regression lines and equation of body weight vs. SV-length in female *Hemidactylus frenatus* for spring, summer and winter. Asterisks indicate equations for absolute body weight which is body weight without tail minus weight of reproductive structure.

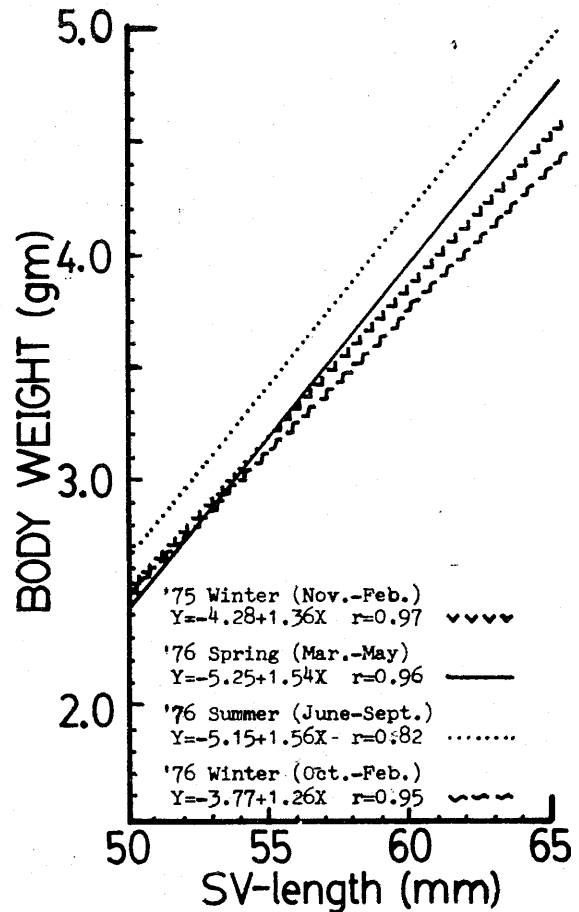


Fig. 4. Regression lines and equation of body weight vs. SV-length in male *Hemidactylus frenatus* for spring, summer and winter.

Livers and fat bodies

The fluctuation patterns of proportionate liver weights were significantly different ($P < 0.02$) (Fig. 5). The proportionate liver weights were slightly higher in summer and lowest in January and February 1976. However, liver weight is subject to many influences, and so apparently its ostensible significant fluctuation pattern may not have a clear biological meaning.

The fat bodies of *H. frenatus*, unlike those of other lizards, appear translucent white and are often difficult to observe. The monthly means of fat body weight showed a distinct

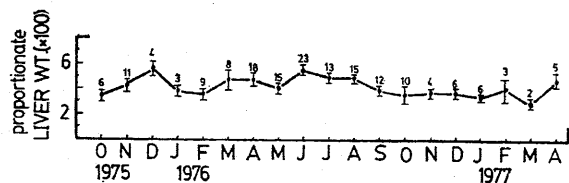


Fig. 5. Monthly changes in proportionate weight of liver in adult female *Hemidactylus frenatus*.

cyclical pattern (Fig. 6). The peak appeared in the winters of 1975 and 1976, when food is least available, and the nutrient states of the geckos were at their worse condition. During the spring and summer of 1976, geckos had relatively small or no fat bodies.

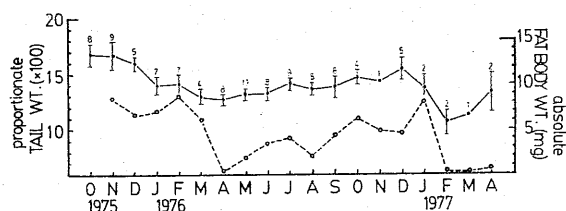


Fig. 6. Monthly changes of proportionate tail weight (solid line) and fat body weight (dotted line) of adult female *Hemidactylus frenatus*. Vertical lines show plus and minus one standard error about the means; number on the top is sample size for each month.

Tail weight

Usually the tail breaks at the definite position at the base of the tail, although it may break at any section.

In females, changes of monthly means of proportionate tail weights showed a distinct cyclical pattern (Fig. 6), essentially similar to the monthly mean changes of fat body weights. They decreased from February, and reached the lowest level in July and August. Thereafter a steady increase began and reached a peak in January and February, when food was least available.

In males, no obvious cyclical pattern was observed in changes of monthly means of proportionate tail weights (Cheng and Lin, 1978). However, they decreased slightly in the spring of 1976 and significantly in the early spring of 1977. There was no obvious correlation in the monthly mean changes between fat body weights and proportionate tail weights in males.

DISCUSSION

The female *H. frenatus* in Taiwan has a definite breeding season from late March to September. Several field observations of population structure show that the most newly hatched individuals (SV-length less than 25 mm) occur from mid-June to early November (unpublished data). Most of these hatchlings will mature in the following spring or summer. Depending on the season in which

the geckos mature, they may produce one or two clutches during the breeding season. Since no geckos greater than 55 mm in SV-length have been captured in March, April and May, it is likely that few adults survive the winter to reproduce in the next breeding season.

The male geckos from the same population have a potentially continuous breeding pattern, but matings are confined mainly to spring and summer (Cheng and Lin, 1977), showing a reproductive synchronization with the females. However, two fecund females were found in the 'non-breeding' season (Fig. 2), and copulations were observed even in the winter (unpublished data). The evidence suggests that some female geckos might also have reproductive potential throughout the year.

It appears that female geckos accumulate fat during the winter. The fat reserves are used in the March and April of the following spring as indicated by the sharp decline in monthly means for fat body weight in these two months. The female geckos must have channelled available energy into reproduction as rapidly as possible in the early months of breeding in order to achieve two clutches in a breeding season. Thus, the fat bodies accumulated in winter appear to be used for the first clutch. However, the variance of the monthly means of the fat bodies is extremely large in the winter months ($CV=26.6-71.2\%$), suggesting that the fat body accumulation at this time depends on the food availability and the variable individual energy consumption for maintenance during the winter. It has been observed that dominant females have usually occupied favourable sites near the light fixtures which ensure them better availability of food and also thermal protection during the winter. These dominant females with sufficient energy accumulation before spring could be the ones that produce the first clutch early in the breeding season.

Tails of geckos often serve as a fat storage site (Bustard, 1967). The monthly proportionate tail weights declined during the

breeding season and only after the cessation of reproductive activities did monthly proportionate tail weights began to increase (Fig. 2 and 6). This suggests that the fat reserves in the tail are used also for the reproductive purpose. Unlike the females in their utilization of fat bodies and reserves in tails, males utilize storage material in these sites not so much for the gonad maturation as to enhance their hierarchical position in terms of territory and food availability.

Energetic stress may cause highly fecund lizards, with multiple broods, to produce smaller clutches and sometimes only a single brood (Ballinger, 1977). In Taiwan *H. frenatus* encounters low food availability during winter as indicated by the amount of food in the stomach, the lower regression lines of body weights on SV-length, and field observations. Less than 60 mg of stomach content per day are found in individuals from October to next February (Table 1 and 2). The average stomach content is 23 mg in winter, 55 mg in spring and 65 mg in summer. Dead geckos, apparently starved to death, are frequently observed during the winter. In line with a population in Java, *H. frenatus* in Taiwan may have the ability for continuous reproduction, if there was abundance of food available to them in winter. However, a few individuals are able to reproduce continuously if the food availability of the microhabitats or local environments in which they live is adequate. Furthermore, *H. frenatus* has catholic tastes and can easily survive on the bread crumbs, sugar and milk to be found in the houses (Church, 1962), so that some individuals may be expected to reproduce in winter, and indeed we did find two fecund females in this season (Fig. 2). Apart from the microhabitat effects on the availability of food, the hierarchical positions of individuals also play a role in determining their nutrient state in the winter.

The cyclical fat storage and utilization system are an important adaptation in lizards to seasonal fluctuation of the environment for reproduction or winter dormancy (Derickson,

1976b). All lizards with a cyclical fat storage and utilization system are expected to be cyclical breeders. The geckos in Taiwan accumulate fat reserves in tails and fat bodies during the winter, when they have the least available energy input and are in the worst nutrient state. Thus, fat accumulation in winter does not appear to be result of energy surplus, but an evolutionary adaptation to the environmental conditions in Taiwan to maximize its reproductive potential. In addition, the cessation of reproductive activity in *H. frenatus* is not a simple response to the scarcity of food. While food is still abundantly available in September, reproduction has already come to an end in both sexes (Table 1 and 2, Cheng and Lin, 1977), suggesting also that the cyclical pattern of reproduction in *H. frenatus* is cued directly to some other environmental factors, other than food stress. Thus, the proximate factors such as photoperiodism and food stress in winter, make the *H. frenatus* a well adapted species in the environment in Taiwan. *H. frenatus* is a cosmopolitan species and appears to have a facultative response to various environmental conditions. It is likely that two or more reproductive strategies could occur within an environmental mosaic. More studies are needed to substantiate this hypothesis.

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臺灣蜥虎 (*Hemidactylus frenatus*) 的卵巢周期 與冬季食量的關係

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臺灣蜥虎卵巢的周期自三月末開始至九月停止，但牠顯然有全年生殖的潛能。雄雌生殖周期同步。最小成熟的吻腔長為 44 公厘。每年六月中旬至十一月為幼蜥虎孵出時期，吻腔長均小於 25 公厘。第二年春天或夏天即告性成熟。每年生殖期間最多可產兩窩。

冬季食物短缺致使蜥虎的營養狀況不如其他季節。但脂肪體及尾部屯積脂肪時期均在冬天發生，可能作為次年第一窩生產的能量來源。臺灣蜥虎雖有整年生殖的能力，但顯然的，冬季食物的缺乏是導致卵巢周期形成的原因。