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GROWTH PATTERN OF THE RED-GIANT FLYING SQUIRREL *PETAURISTA PETAURISTA* IN TAIWAN

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The growth pattern of the immature red-giant flying squirrel *Petaurista petaurista* was studied in Taiwan using harvest data. Growth of body sizes (i.e., body weight, lengths of body, tail, ear, hindfoot, and styliform cartilage) did not differ significantly between youngs born in winter and summer ($p>0.05$ for all comparisons). Sexual differences also were not significant ($p>0.05$). Weights of young increased throughout the study period, but was the slowest body development among the characters. Weight gain in the first 7–8 months was rapid and linear. Squirrels attained adult weight at 10–12 months. The development of body length was similar. The ear growth rate was the most rapid of the characters, with the hindfoot growth rate next. At about 4–5 months the ear, hindfoot, tail and styliform cartilage were all adult size.

Information on the growth of body sizes under natural condition aids in understanding the life-history strategies of animals (Zullinger *et al.*, 1984; Leberg *et al.*, 1989). Growth rate data are also of value in deriving age equations for use in behavioral, physiological and ecological studies (Case, 1978).

Although the Formosan red-giant flying squirrel (*Petaurista petaurista*) is one of the most widely distributed giant flyin squirrel species in montane forests of souheast Asia (Honacki *et al.*, 1982; Nowak and Paradiso, 1983), little is known of its postnatal growth patterns. Data on the life history characteristics of giant flying squirrels are difficult to gather partly because they are nocturnal and highly arboreal (Muul and Lim, 1978; Lee *et al.*, 1986). In a study on the reproduction of *P. petaurista* in Taiwan, this species was shown to have two distinct breeding seasons (December-February and June-August) per year with 1.03 young per litter (Lee, 1983). Young was born mainly in February and August. This highly synchronized breeding pattern provides a way to trace the development of the immature squirrels and to estimate the growth rates for individuals born in different seasons.

In this paper we describe the growth pattern of immature *P. petaurista* using cross-sectional data (*i.e.*, harvest data), in which each individual was collected and measured only once. Postnatal growth patterns of young born either in winter or summer in lower hardwood forests in Taiwan were monitored for body length, tail length, hindfoot length, ear length and styliform cartilage length and body mass, as a function of estimated age in months.

METHOD

We collected 281 squirrels in Sunmin (23°13′N and 120°41′E) in southern Taiwan between December 1981 and November 1982. Sunmin, at an elevation of 500 m, is a valley surrounded by hardwood forests with most of the trees belonging to Lauraceae and Fagaceae. The study area is described in detail in Lee (1983). Sixty-five squirrels were identified as immature based on reproductive characteristics and body measurements. For each squirrel, we measured, to the nearest mm, the lengths of body, tail, hindfoot, ear, and styliform cartilage. Ages for immature specimens were determined to the nearest month based on body mass, month of capture, overall physical development, and reproductive condition. Two groups of immatures were identified: young born in Januray-Febary 1981 (n=6) and 1982 (n=28), and young born in July-August 1981 (n=30) and 1982 (n=1). The sex ratio of juvenile favored females (1.8 : 1). Data were combined across years, and the growth patterns were compared for immature squirrels born in summer and winter.

A female squirrel, born and captured in late January 1982, was retained in captivity and fed on milk and sweet potatoes. Weight was obtained periodically during February 1982–83.

It was difficult to determine the exact for wild born immatures. We assumed that all squirrels born in winter were born at the end of January, and those from summer were born at the end of July. We then estimated the growth pattern for our samples based on the interval from these data. Although this assumption may create greater variance in the monthly samples and possibly biased estimates of growth rate (Leberg *et al.*, 1989), we believed that this approach gave a good prediction of squirrel growth after comparing to the captive data.

Because mammalian growth is asymptotic (Leberg *et al.*, 1989), we used a sigmoid growth function (Zullinger *et al.*, 1984) to approximate the growth pattern of our samples. The relationship between body measurements and age was examined using the allometric model $Y=aX^b$ where Y=squirrel body weight (g) or other length measurements (mm), X=squirrel's estimated age in months, and a and b are unknown estimates (Nixon *et al.*, 1991). We used natural logarithms to convert the equation to a linear form and applied simple linear regression to find the estimates of a and b. A t-statistic (Sachs, 1982) was used to test the equality of the two regression lines from our two groups of immature squirrels.

RESULTS AND DISCUSSION

Immature squirrels ranged from 136 to 1331 g in weight and between 178 and 390 mm in body length. Mean body mass (± SD) for adult males and females was 1260 (± 122) and 1335 (± 135) g, respectively, and mean body length was 379 (± 14) and 377 (± 14) mm respectively (Lee, 1983). We assumed that this species achieved sexual maturity after 12 months of age as there was no indication of sexual maturity in any of our samples.

Except for two squirrels captured from tree cavities in their second month of age, young of the year were first observed in the field at about 3–4 months old (November for summer-born and April for winter-born young) when weighed 300–600 g and were 250–280 mm in body lenth (Lee, 1983). This suggests that the possible weaning age for *P. petaurista* is at about 90 days postpartum. Muul and Lim (1978) reported that a young *Petaurista petaurista* in peninsular Malaysia required 90–120 days for full physical development. This compares to the 60 to 80 days for the southern flying squirrel (*Glaucomys volans*) in the United States (Sonenshine *et al.*, 1979).

Growth of squirrels did not differ significantly between young born in winter and summer ($p>0.05$ for all comparisons). Sexual differences also were not significant ($p>0.05$). Thus, all data were pooled to estimate the growth pattern.

Weights of young *P. petaurista* increased throughout the first 12 months postpartum (Fig. 1), but this was the slowest body development among the measurements. At birth these squirrels may weigh more than 50 g (Lee, 1983). Squirrels attained 20% of the average adult male weight at three months, 50% at four months, 75% at seven months, 90% at ten months, and 100% at 10–12 months (Fig. 1). Weight gain in the first 7–8 months was rapid and linear. The point of inflection in body weight, when weight gain begins to decline, occurred at about eight months of age. This growth pattern is similar to other similarly sized sciurids such as the North American fox squirrel (*Sciurus niger*) (Nixon *et al.*, 1991). Smaller sciurids, e.g., *G. volans* (Linzey and Linzey, 1979; Sonenshine *et al.*, 1979) and southern African tree squirrels (*Funisciurus* spp. and *Paraxerus* spp.) (Viljoen and Du Toit, 1985), apparently exhibit reflection in weight gain at younger ages than immature red-giant flying squirrels.

Although we did not trace the development of litters as did previous researchers (e.g., Clark, 1970; Linzey and Linzey, 1979; Nixon *et al.*, 1991), calculated gain in body mass based on field data compared closely with that of our single captive squirrel. This squirrel reached 50% of adult body mass at four months of age and gained weight most rapidly during the first five months postartum. Between 9 and 12 months old, the squirrel grew from 850 to 1200 g.

Development of body length showed

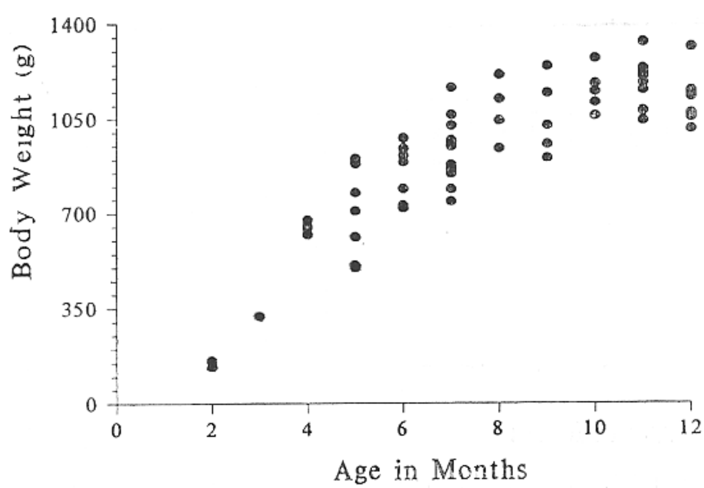

Fig. 1. Body weight as a function of age in months for 65 juvenile red-giant flying squirrels captured in Taiwan between December 1981 and November 1982.

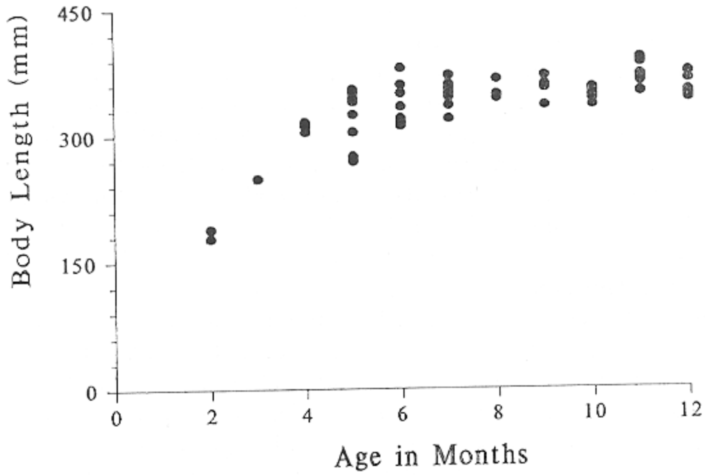

Fig. 2. Body length as a function of age in months for 65 juvenile red-giant flying squirrels captured in Taiwan between December 1981 and November 1982.

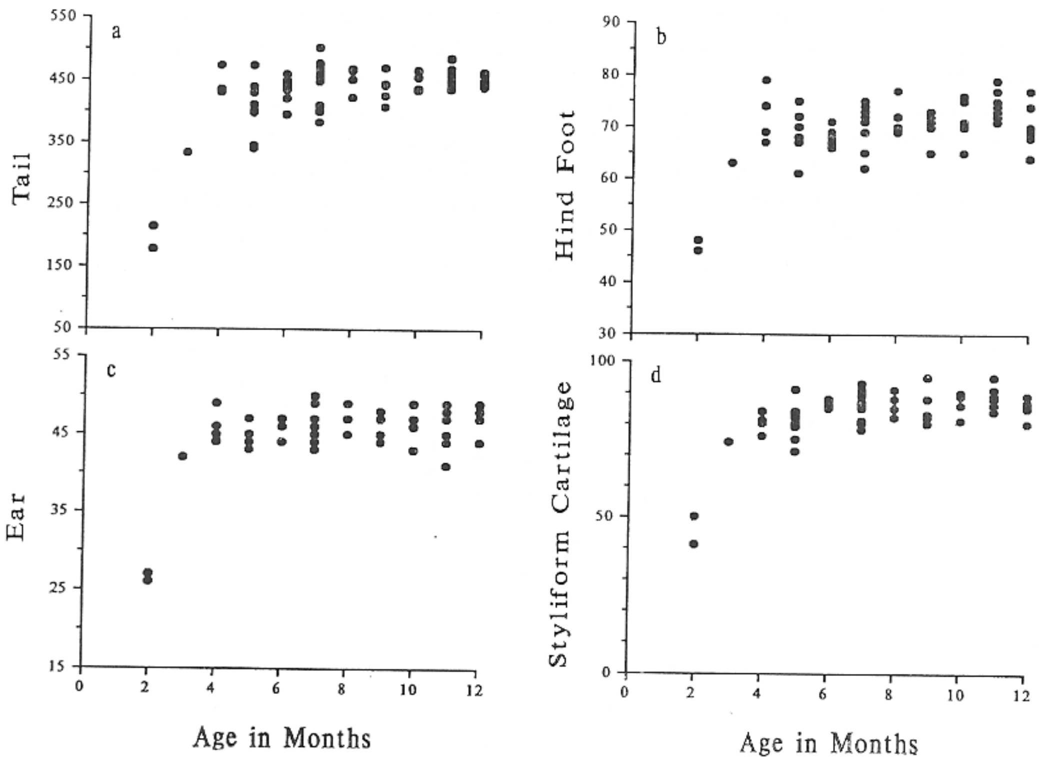

Fig. 3. Length of tail (a), hindfoot (b), ear (c), and styliform cartilage (d) as a function of age in months for 65 juvenile red-giant flying squirrels captured in Taiwan between December 1981 and November 1982.

more rapid growth pattern compared to body mass (Fig. 2). Squirrels reached 50% adult length when two months old and most squirrels had attained adult length at about six months of age.

The other body measurements grew even faster. The developments of the tail, hindfoot, ear, and styliform cartilage with respect to age are shown in Figs. 3a-d, respectively. Ear growth was the most rapid among the four characteristics, with hindfoot growth next. At estimated 4-5 months postpartum the ear, hindfoot, tail, and styliform cartilage were all adult size (Fig. 3).

It is possible that some squirrels continue to gain body mass after reaching sexual maturity because the maximum body weight of adult squirrels can be as high as 1500 g (Lee, 1983). In contrast, the development of other morphological character, i. e., lengths of body, tail, hindfoot, ear, and styliform cartilage were relatively stable after reaching sexual maturity. This is similar to the growth pattern found in *G. volans* (Linzey and Linzey, 1979). Compared to other smaller sciurids such as the North American Richardson's ground squirrels (*Spermophilus richardsoni elegans*) (Clark, 1970), and the African squirrel *Funisciurus* spp. and *Paraxerus* spp. (Viljoen and Du Toit, 1985), *P. petaurista* showed slower growth rates. In general, however, the overall growth pattern of immature *P. petaurista* observed in this study is similar to other sciurids.

The results reported in this paper are preliminary. Use of harvest data to estimate growth pattern is limited by several factors, such as the level of precision in age estimation, biased samples due to age class collected, and yearly variation of animal population due to food sources (Leberg *et al.*, 1989) The possible systematic error introduced by our method of analysis due to inaccurate age estimation tends to be balanced by using the assumed date of the exact birth day for the entire group of squirrels because it represents a midpoint for the birth period. Overall, the data presented here show a general qualitative growth pattern of *P. petaurista* that is of value to our understanding of the physical growth of maturation of giant flying squirrels.

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臺 灣 產 大 赤 鼯 鼠 之 成 長

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本文探討臺灣地區大赤鼯鼠 *Petaurista petaurista* 幼鼠的成長模式。研究的形值特徵包括體重、體長、尾長、耳殼長、後足掌長與翼形軟骨長 (styliform cartilage)，結果顯示冬天出生與夏天出生幼鼠間的體型大小並沒有顯著的差異 ($p>0.05$)；亦沒有性別的差異 ($p>0.005$)。耳殼長是成長最快速的形值變數；而後足掌長次之。大約 4～5 個月時，尾長、耳殼長、後足掌長、與翼形軟骨長就可達成鼠的尺寸。幼鼠的體重增加速率較其他形值慢，在出生後的前 7 至 8 個月體重以線性的方式迅速增加，而 10～12 個月時即可達到成鼠的體重。體長增加的情形與體重類似。