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Body Size Comparison of Two Giant Flying Squirrel Species in Taiwan

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Abstract

I report body size measurements of *Petaurista petaurista* ($n = 216$) and *P. alborufus* ($n = 51$) in Taiwan, compare differences between adult squirrels of opposite sex and between the two species, and offer linear regression equations for predicting body weight from body length. Average body weight of female *P. petaurista* was significantly greater than that of males. Other morphological characters, i.e., lengths of body, tail, ear, hind foot, and styliform cartilage, were not significantly different between the two sexes ($p > 0.05$) in *P. petaurista*. There were no differences in body size measurements between adult males and adult females of *P. alborufus*. *P. alborufus* was significantly larger than *P. petaurista* in body weight (1522 vs. 1295 g), body (394 vs. 377 mm), tail (474 vs. 459 mm), and hind foot length (75.0 vs. 72.9 mm), but significantly shorter in styliform cartilage length (82.1 vs. 87.7 mm). There is no difference in ear length between the species. The linear regression using log-transformed body weight (Y) and body length (X) for the two species shows significant differences and the lines account for 78% and 37% variations in *P. petaurista* and *P. alborufus*, respectively.

Keywords: *Petaurista petaurista, Petaurista alborufus*, body weight, linear regression

INTRODUCTION

Some of the easiest data one can collect once an animal is caught concern the body size, including body weight, and lengths of body, tail, etc. In addition to taxonomy, body weight (or mass) is the single most important datum for any mammal species (Silva and Downing, 1995). Body weight information allows one to predict numerous features of the organism's physiology, morphology, life history, and sometimes its ecological role (Peters, 1983; Lidicker, 1997). It is also important in biogeography studies that compare life history characteristics of the same species across broad geographic regions.

Although much is known about body weight among mammals, information on the giant flying squirrels (genus *Petaurista*) distributed in Asia is largely lacking or inconsistent (Silva and Downing, 1995). The greatest diversity of sciurid flying squirrels occurs in Southeast Asia (Muul and Lim, 1978). The giant flying squirrel distributed in montane forests of Afghanistan and the Himalayas, south through India, through central and southern China, Japan, Taiwan, Thailand, and Indo-Malaysia, to Java and Borneo (Wilson and Reeder, 1993). Two species (*P. petaurista* and *P. alborufus*) occur in Taiwan. Silva and Downing (1995) summarized data on body mass for *Petaurista* species from diverse literature sources. They showed that adult *P. alborufus* in Thailand was 4.29 kg in body mass, and adult *P. petaurista* has a body mass ranging from 1.0 to 3.19 kg in wide geographical areas.

Corbet and Hill (1992) reviewed *Petaurista* species, recognized *philippensis* as distinct, and changed the taxonomic status of many of those former assigned to *P. petaurista* to *P. philippensis*, including the species in Taiwan (Wilson and Reeder, 1993). Since there are comparatively few the studies of the giant flying squirrel remain (Lin *et al.*, 1985), these changes in taxonomic status may need further comprehensive studies (Corbet and Hill, 1992). In this paper I use *P. petaurista*, instead of *P. philippensis*, to represent the red-giant flying squirrel in Taiwan.

In an effort to contribute scientific knowledge on the *Petaurista* species, I report body size measurements of *P. petaurista* and *P. alborufus* in Taiwan. In particular, I compare body size differences of adult squirrels between different sexes and species, and offer regression equations for predicting body weight from body length.

MATERIALS AND METHODS

Squirrels were collected from hardwood forests near Sunmin Village, southern Taiwan (23°13'N and 120°41'E) between December 1981 and November 1982 and Chitou (23°40'N, 120°47'E) between December 1981 and September 1982. Lee *et al.* (1993b) provide a detailed description of Sunmin, and Lee *et al.* (1993a) document the study area in Chitou.

I collected 281 *P. petaurista* (all from Sunmin) and 77 *P. alborufus* (67 from Sunmin and ten from Chitou). Each squirrel was weighed on a custom-built spring scale accurate to 0.1 g, and the lengths of body, tail, ear, hind foot, and styliform cartilage (a distinct entepicondylar foramen at the distal end of the humerus, and a primitive character not found in most rodents) were measured. I used the information extracted from reproductive organs to classify age classes (see Lee *et al.*, 1993b for details). Both species show similar reproductive characteristics and patterns. Therefore, I used the criteria in Lee *et al.* (1993b) to separate adults from subadults and juveniles. Data for *P. alborufus* at Chitou were all from adults, and they did not differ in body size measurement with those collected at Sunmin. Therefore, I combined both data sets in the analysis. I have 216 adult *P. petaurista* (116 males, 100 females) and 51 *P. alborufus* (30 males, 21 females) for body measurement comparison. Statistical assumptions of these tests were checked and no serious departures were found. Student's *t*-tests were performed using SYSTAT (SYSTAT, 1997) to compare body size differences between species, and between different sexes in the same species. I used a simple linear regression with adult, subadult, and juvenile data to explore the relation between body weight and body length. Both variables were first LOG10 transformed.

RESULTS

Table 1 shows the morphological characteristics of adult *P. petaurista* and *P. alborufus*. Average body weight of female *P. petaurista* was significantly greater than that of males ($p < 0.001$). Other morphological characters, i.e., lengths of body, tail, ear, hind foot, and styliform cartilage, were not significantly different between the two sexes ($p > 0.05$) in *P. petaurista*. There were no differences in body size measurements between adult males and adult females of *P. alborufus* (*t*-test, $p > 0.05$). *P. alborufus* was significantly larger than *P. petaurista* in body weight (1522 vs. 1295 g, $t = 9.88$, $p < 0.001$), body length (394 vs. 377 mm, $t = 5.42$, $p < 0.001$), tail length (474 vs. 459 mm, $t = 3.88$, $p < 0.001$), and hind foot length (75.0 vs. 72.9 mm, $t = 3.99$, $p < 0.001$), but shorter in styliform cartilage length (82.1 vs. 87.7 mm, $t = -6.69$, $p < 0.001$). There is no difference in ear length between the species.

Although there is a significant difference in body weight between the two sexes of adult *P. petaurista*, the difference between two simple linear regression equations for the opposite sexes was small ($p > 0.05$). Therefore, the pooled regression line was used. Fig. 1 shows the relation of body weight and body length for *P. petaurista* and *P. alborufus*. The simple lin-

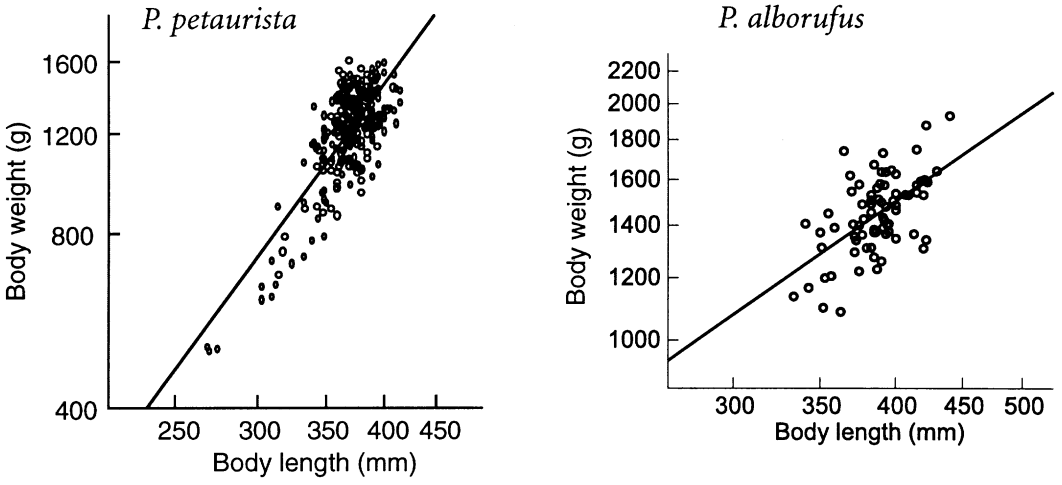

Figure 1. Relationships of body length and body weight for *Petaurista petaurista* and *P. alborufus* in Taiwan

Table 1. Body size comparison for *Petaurista petaurista* and *P. alborufus* in Taiwan. NS, $p > 0.05$; ***, $p < 0.001$.

Measurement	*Petaurista alborufus*			*Petaurista petaurista*			Species difference *t*-test
	Male ($n = 30$)	Female ($n = 21$)	t-test	Male ($n = 116$)	Female ($n = 100$)	*t*-test	
Body weight (g)							
Mean (standard deviation)	1508 (144)	1541 (162)	NS	1260 (122)	1335 (135)	***	***
Range	1231-1930	1223-1877		989-1569	1005-1597		
Body length (mm)							
Mean (standard deviation)	393 (23)	395 (16)	NS	378 (14)	377 (14)	NS	***
Range	349-440	365-422		350-415	342-415		
Tail length (mm)							
Mean (standard deviation)	472 (21)	476 (26)	NS	457 (25)	460 (25)	NS	***
Range	433-515	421-523		405-506	381-515		
Hind foot length (mm)							
Mean (standard deviation)	76 (3)	75 (4)	NS	72 (3)	73 (4)	NS	***
Range	68-84	69-83		64-81	65-83		
Ear length (mm)							
Mean (standard deviation)	46 (3)	47 (2)	NS	47 (2)	47 (2)	NS	NS
Range	40-52	41-50		39-54	42-51		
Styliform length (mm)							
Mean (standard deviation)	82 (6)	83 (5)	NS	88 (5)	88 (4)	NS	***
Range	72-93	70-90		64-102	79-102		

ear regression prediction for *P. petaurista* is

LOG (body weight in g) = -3.961 + 2.742 LOG (body length in mm)

with $r^2 = 0.78$ ($F = 978.47$, $p < 0.001$, df = 1, 279).

And the equation for *P. alborufus* is

LOG (body weight in g) = -0.420 + 1.383 LOG (body length in mm)

with $r^2 = 0.37$ ($F = 45.99$, $p < 0.001$, df = 1, 75). The prediction lines for these two species were significantly different ($p < 0.001$).

DISCUSSION

Despite their wide geographical distribution, information on giant flying squirrel species remains relatively sparse especially in the China and Indo-Malayan regions. Little is known about the biological characteristics of *Petaurista* (Lin *et al.*, 1985), except for scattered reports based on few specimens (e.g., Roberts, 1977; Medway, 1978, Corbet and Hill, 1992). Since Taiwan is the most eastern boundary of the distribution of *P. alborufus* and *P. pataurista*, the information in Taiwan should contribute much important knowledge to our understanding of these two species.

This study shows that the body weight for the adult giant flying squirrel species is in the range from 989 to 1930 g. The result is similar to that of Nowak (1991), who reported that the weight of giant flying squirrel was about 1000-2500 g. The body weight for adult *P. petaurista* in Taiwan was similar to those reported from Pakistan (1137-1704 g, n = 10, Roberts, 1977), Thailand (1700 g, no sample size given, Lekagul and McNeely, 1977; cited in Rabinowitz, 1990), and Malaysia and Singapore (1000-1700 g, no sample size given, Harrison, 1964, 1974), but smaller than those reported by Medway (1978) in Malaya (1596-2450 g, n = 6) and Silva and Downing (1995) in Himalayan Mountains (3190 g, no sample size given). If all measurements are correct, body weight differences in *P. petaurista* in different geographical areas may have important contributions to the life history characteristics and taxonomic status. Because most of the body weight measurements for this species were based on relatively small sample sizes, except this study, a more comprehensive study on this species across its geographical areas should be conducted to clarify the taxonomy issues raised by Corbet and Hill (1992).

There is even less information on *P. alborufus* when compared to *P. petaurista*. Adult body weight for this species in Taiwan is in the range of 1223 to 1930 g which is significantly smaller than the body weight of 4290 g reported by Corbet and Hill (1992) in China and by Lekagul and McNeely (1977, cited in Silva and Downing, 1995) in Thailand. Since the data summarized in Corbet and Hill (1992) and Silva and Downing (1995) were based on museum records and small sample sizes, these data are doubtful and further data need to be collected.

The two species are sympatric in many forested areas in Taiwan (Lee *et al.*, 1998), and they appear to show no direct competition based on direct field observation (Lee *et al.*, 1986; 1993a). Because these species are arboreal folivores, one of the reasons suggested is the abundant food items (Lee *et al.*, 1986). With the significant difference in body sizes of *P. petaurista* and *P. alborufus* found in this study, the selective difference in tree cavity as nest and resting sites due to different body size may be a potential resource-partitioning factor for these two species.

The predictive equation for *P. alborufus* is less accurate than the one for *P. petaurista* based on the squared correlation coefficients (the coefficient of determination). This is due to the small sample size in *P. alborufus*, especially in the young and subadult classes and is also due to a greater body size variation in adults. The simple linear regression equation for *P. alborufus* should be used with caution when dealing with smaller individuals.

Body weight of *P. alborufus* is significantly larger than that of *P. petaurista*, but the styliform cartilage shows the reverse pattern. The cartilage acts like a spur to stretch the patagium when the animal is in flight. The flap of skin (patagium), which acts as a parachute in gliding, stretches from the wrist to the metacarpal joint of the hind leg. Except for small blood vessels, the membrane consists simply of a fold of hair-covered skin. I did not measure the patagium sizes of these species, but my experience has shown that the patagium for *P. alborufus* is larger and thicker than that of *P. petaurista*. The significance of combined differences of styliform cartilage, patagium, and other body sizes between the two

species remain to be studied. *Petaurista* species have the ability to glide for a long distance (Nowak, 1991), which is also an important adaptation promoting the evolution of longevity (Holmes and Austad, 1994). I suspect the size differences in patagium and styliform cartilage between the species reflect differences in gliding ability, and thus, affect their life history characteristics. Further comparative morphology and ecological studies are needed to confirm this.

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REFERENCES

Corbet, G. B. and J. E. Hill (1992) *The mammals of the Indomalayan region: a systematic review*. Oxford University Press, Oxford, 488 pp.

Harrison, J. L. (1964) *An introduction to the mammals of Sabah*. Tien Wah Press, Signapore, 244 pp.

Harrison, J. L. (1974) *An introduction to mammals of Singapore and Malaya*. 2nd ed. Malayan Nature Society, Singapore, 340 pp.

Holmes, D. J. and S. N. Austad. (1994) Fly now, die later: life history correlates of gliding and flying in mammals. J. Mamm. 75: 224-226.

Lee, P. F., D. R. Progulske and Y. S. Lin (1986) Ecological studies on two sympatric *Petaurista* species in Taiwan. Bull. Inst. Zool., Academia Sinica 25: 113-124.

Lee, P. F., D. R. Progulske and Y. S. Lin (1993a) Spotlight counts of giant flying squirrels (*Petaurista petaurista* and *Petaurista alborufus*) in Taiwan. Bull. Inst. Zool., Academia Sinica 32: 54-61.

Lee, P. F., K. Y. Lue, J. C. Hsieh, Y. C. Lee, Y. H. Pan, H. W. Chen, T. C. Pan and T. S. Ding (1998) *A wildlife distribution database in Taiwan*. Council of Agriculture, Taipei, 406 pp. (In Chinese, English abstract)

Lee, P. F., Y. S. Lin and D. R. Progulske (1993b) Reproductive biology of the red-giant flying squirrel, *Petaurista petaurista*, in Taiwan. J. Mamm. 74: 982-989.

Lekagul, B. and J. A. McNeely (1977) *Mammals of Thailand*. Association Conservation Wildlife, Sahakarnbhat Co., Bangkok, 758 pp.

Lidicker, W. Z., Jr. (1997) Reviews on *Handbook of mammalian body masses*, by M. Silva and J. A. Downing. J. Mamm. 78: 987-988.

Lin, Y. S., D. R. Progulske, P. F. Lee and Y. T. Day (1985) Bibliography of Petauristinae (Rodentia, Sciuridae). J. Taiwan Mus. 38(2): 49-57.

Medway, L. (1978) *The wild mammals of Malaya (Peninsular Malaysia) and Singapore*. 2nd ed. Oxford University Press, Oxford, 128 pp.

Muul, I. and L. B. Lim (1978) Comparative morphology, food habits, and ecology of some Malaysian arboreal rodents. In *The ecology of arboreal folivores*. G. G. Montgomery, ed. Smithsonian Institution, Washington, D.C., pp 361-368.

Nowak, R.M. (1991) *Walker's mammals of the world*. 5th ed. Voulme 2. The Johns Hopkins University Press, Baltimore, 1629 pp.

Peters, R. H. (1983) *The ecological implications of body size.* Cambridge University Press, Cambridge, 329 pp.

Rabinowitz, A. (1990) Notes on the behavior and movements of leopard cats, *Felis bengalensis*, in a dry tropical forest mosaic in Thailand. Biotropica 22: 397-403.

Roberts, T. J. (1977) *The mammals of Pakistan.* Ernest Benn Limited, London, 361 pp.

Silva, M. and J. A. Downing (1995) *Handbook of mammalian body masses.* CRC Press, Boca Raton, 359 pp.

SYSTAT (1997) *SYSTAT 7.0 for Windows.* SPSS, Inc., Chicago, 2000 pp.

Wilson, D. E. and A. E. Reeder, editors (1993) *Mammal species of the world: a taxonomic and geographic reference.* 2nd ed. Smithsonian Institution Press, Washington, D.C., 1206 pp.

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台灣產大型飛鼠之形態比較

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摘 要

本研究比較大赤鼯鼠（*Petaurista petaurista*）和白面鼯鼠（*P. alborufus*）之外部形態特徵。大赤鼯鼠之樣品取自高雄縣三民鄉，共281隻，白面鼯鼠之樣品分別取自三民鄉（67隻）與南投縣溪頭（10隻），共77隻。結果發現成熟的大赤鼯鼠，雌鼠的體重明顯大於雄鼠，但在其他形態特徵（體長、尾長、耳長、後腳長和翼手骨）上則無差異。成熟的白面鼯鼠雌雄間在體重、體長、尾長、耳長、後腳長和翼手骨上均無明顯的差異。白面鼯鼠在體重、體長、尾長和後腳長上均高於大赤鼯鼠，但翼手骨則相反。直線迴歸所得到體長和體重之關係，顯示兩種飛鼠之預測方程式有明顯的差異，而大赤鼯鼠的直線迴歸式可解釋78%的變異，但白面鼯鼠的直線迴歸式僅達37%。

關鍵詞：大赤鼯鼠、白面鼯鼠、體重、直線迴歸