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Spotlight counts of giant flying squirrels (*Petaurista petaurista* and *P. alborufus*) in Taiwan

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We studied population trends for two sympatric flying squirrels (*P. petaurista* and *P. alborufus*) via night spotlight counts from October, 1981 to August, 1984 in Chitou, Taiwan. A total of 298 *P. petaurista,* 281 *P. alborufus,* and 2,722 calls (337 *P. petaurista,* 2,385 *P. alborufus*) were recorded over 107 nights. Monthly mean densities (squirrels/10 ha) of *P. petaurista* and *P. alborufus* observed in hardwood forests were significantly higher than those observed in conifer plantations ($p < 0.01$). In hardwood forests, *P. alborufus* were equally abundant as *P. petaurista,* but in conifer plantations the latter was significantly more abundant than the former ($p < 0.001$). *P. alborufus* densities in hardwood forests showed seasonal differences ($p < 0.001$), with the highest in fall ($\bar{x}$ = 4.2 squirrels/10 ha, SE = 0.08) and the lowest in winter ($\bar{x}$ = 2.2 squirrels/10 ha, SE = 0.19); the *P. petaurista* populations in both habitats showed no seasonal variations. *P. petaurista* densities observed in hardwood forests were positively correlated with those of *P. alborufus* in the same habitat, but no correlations were found in the other situation. Call indexes for both species did not correlate with the estimated densities.

Keywords: Giant flying squirrel, *Petaurista,* Population trend.

Giant flying squirrels (*Petaurista* spp.) have the highest diversity in terms of species richness and population density in southeast Asia (Honacki *et al.* 1982). Five species have been recognized: *P. alborufus, P. elegans, P. leucogenys, P. magnificus,* and *P. petaurista* (Nowak and Paradiso 1983). Among these, only the ecology of *P. leucogenys* has been extensively studied in Japan (e.g., Baba 1978, Ando and Imaizumi 1982, Baba *et al.* 1982, Ando *et al.* 1983, 1984, Ando and Shiraishi 1983, 1984). No study has been made on the population trends of giant flying squirrels.

Taiwan has two *Petaurista* species: the Formosan red-giant flying squirrel (*P. petaurista*) and the Formosan white-headed flying squirrel (*P. alborufus*) (Jones *et al.* 1971). Both species are arboreal folivores which rely on forest habitat (Muul and Lim 1978, Lee *et al.* 1986). They primarily use tree cavities as nests during the daytime. Previous studies have revealed that these two species do not overlap in their distributions (Kano 1940); however, Lee *et al.* (1986) recently found that both species live sympatrically in mountain forests at elevations between 1,100 and 1,500 m.

The two species show several differences in body size, distribution, and ecological requirements. *P. alborufus* adults have larger average body weights than *P. petaurista* (1,479 vs. 1,285 g) (Lee *et al.* 1986). Both Kano (1930) and McCullough (1974) reported that *P. petaurista* is most abundant in lower elevations of broad-leafed hardwood forests, whereas *P. alborufus* is more common in natural conifer forests at higher elevations. Both species appear ecologically tolerant of each other while feeding or resting (Lee *et al.* 1986, Lin *et al.* 1988). Slight differences in the use of vertical forest dimensions have been found: *P. petaurista* usually uses lower vegetation layers for daily activities, while *P. alborufus* uses higher layers (Lee *et al.* 1986).

Petaurista spp. are major game species in Taiwan; it is not clear how hunting affects populations of both species since information pertaining to the population trends of these squirrels is lacking. We investigated *P. petaurista* and *P. alborufus* population trends in areas where both species live sympatrically in central Taiwan from October, 1981 to August, 1984 using a spotlight method.

METHODS

The study was conducted at the Chitou Experimental Forest of National Taiwan University in central Taiwan (23°40'N, 120°47'E). The study area is described in detail in Lee *et al.* (1986).

We made our observations along three paved mountain trails which extend into conifer and hardwood forests. The tails are 6.7, 3.6, and 2.5 km in length, with elevation changes from 1,100 to 1,525, 1,340, and 1,360 m, respectively. Assuming that the effective range of a spotlight is about 60 m (Lee *et al.* 1986), these tails cover approximately 74% of the conifer plantations and 26% of the hardwood forests within the Experimental Forest.

Squirrels were counted 2-4 nights per month between 1800-2400 hrs — when these squirrels are most active (Lin *et al.* 1988). Using a different trail each night, we made three observations per month until August, 1983, when serious erosion destroyed the shortest trail. We then concentrated on the other two trails and made observations on each one twice per month. Lee *et al.* (1986) have previously described in detail the method used to locate squirrels. We attempted to identify habitat whenever a squirrel was sighted. At the same time, we counted squirrels calls based on their distinct vocalizations (Lee *et al.* 1986). No attempt was made to determine the exact locations of calling squirrels due to the high degree of potential error.

Monthly squirrel densities were expressed as total numbers observed per month per 10 ha of studied habitat. To reduce double counting bias, after August, 1983 monthly squirrel densities were calculated by averaging two sampling counts. Our call count index was calculated in the same way without distinguishing habitat type. To better understand seasonal patterns, monthly means were grouped seasonally: fall (September — November), winter (December — February), spring (March — May), and summer (June — August). Relationships between population densities and call count indexes, and between population densities of *P. petaurista* and *P. alborufus* in two habitats (conifer plantation and hardwood forest) were characterized using Pearson's correlation coefficients. Differences in estimated squirrel densities were compared using a Student *t*-test or an *F*-test. Normality assumptions were checked, and no serious departures were found.

The biological assumptions used in this study were: (1) all animals within the effective range of spotlights were seen with equal probability, (2) no animal was counted twice on the same night, (3) animals were randomly distributed along the transects, (4) each sighting was an independent event, and (5) animals did not move before being sighted (Anderson *et al.* 1979, Davis and Winstead 1980). Except for the first and third assumptions, all assumptions were met since flying squirrels are slow movers, are solitary most of the time, and tend to remain in one spot to feed or rest for an extended period of time (Lee *et al.* 1986, Lin *et al.* 1988). Based on our previous field experience, we believe the estimates are reliable.

Environmental variables (i.e., temperature, relative humidity, wind speed, cloud cover, visibility at 2100 h, and evaporation rate during daytime) were obtained from the weather station located at Chitou for those days when surveys were conducted. Average values were used to correlate observed densities of squirrel populations and call count data.

RESULTS

For the following numbers, "CP" refers to conifer plantation, and "HF" refers to hardwood forest. A total of 298 *P. petaurista* (115 CP, 183 HF), 281 *P. alborufus* (32 CP, 249 HF), and 2,722 calls (337 *P. petaurista* and 2,385 *P. alborufus*) were recorded over 107 nights.

Average monthly densities of squirrels observed in hardwood forests were significantly higher than those observed in conifer plantations for both *P. petaurista* and *P. alborufus* ($p < 0.01$ for both cases) (Table 1). In hardwood forests, *P. alborufus* and *P. petaurista* were equally abundant ($F = 3.5$; $df = 1, 68$; $0.10 > p > 0.05$), but in conifer plantations, the latter had a greater density than the former ($F = 31.7$; $df = 1, 68$; $p < 0.001$). The density difference for *P. petaurista* between the two habitat types was less than that for *P. alborufus*.

P. alborufus population trends in both conifer plantations and hardwood forests indicate a seasonal pattern (Fig. 1a). In hardwood forests, *P. alborufus* densities showed seasonal differences ($F = 30.5$; $df = 3, 8$; $p < 0.001$) with the highest in fall ($\bar{x} = 4.2$ squirrels/10 ha, SE = 0.08, $n = 3$), the lowest in winter ($\bar{x} = 2.2$ squirrels/10 ha, SE = 0.19, $n = 3$), and with intermediate densities in spring ($\bar{x} = 2.8$ squirrels/10 ha, SE = 0.21, $n = 3$) and summer ($\bar{x} = 2.9$ squirrels/10 ha, SE = 0.08, $n = 3$). Occurrences of *P. alborufus* in conifer plantations were

Table 1. Population estimates (squirrels/10 ha, $\bar{x} \pm SE$) of *Petaurista petaurista and P. alborufus* by spotlight count in conifer plantations and hardwood forests from October, 1981 to August, 1984 in Chitou, Taiwan.

Forest type	*Petaurista petaurista* ($n = 35$)				Petaurista alborufus ($n = 35$)			
	$\bar{x}$	SE	Min.	Max.	$\bar{x}$	SE	Min.	Max.
Conifer plantations	0.56	0.06	0.00	1.95	0.15	0.03	0.00	0.89
Hardwood forests	2.35	0.20	0.51	5.56	2.98	0.27	0.89	7.27
Total	1.04	0.08	0.26	2.23	0.92	0.08	0.26	2.29

sporadic. Overall, the *P. alborufus* population was relatively stable throughout the study period.

P. petaurista population densities were also relatively stable, but with a slight decrease toward the end of the study period (Fig. 1b). No seasonal differences in squirrel densities in both habitats were found ($p > 0.05$ for both cases). Mean (± SE) densities in hardwood forests for *P. petaurista* in fall, winter, spring, and summer were 2.3 (0.05), 2.2 (0.28), 2.5 (0.56), and 2.4 (0.47), respectively; for conifer plantations they were 0.6 (0.04), 0.4 (0.15), 0.7 (0.30), and 0.5 (0.14), respectively. Except in November, 1981 and April, 1982, when *P. petaurista* densities were higher in conifer plantations than in hardwood forests, monthly population trends indicate that *P. petaurista* was more abundant in hardwood forests than in conifer plantations.

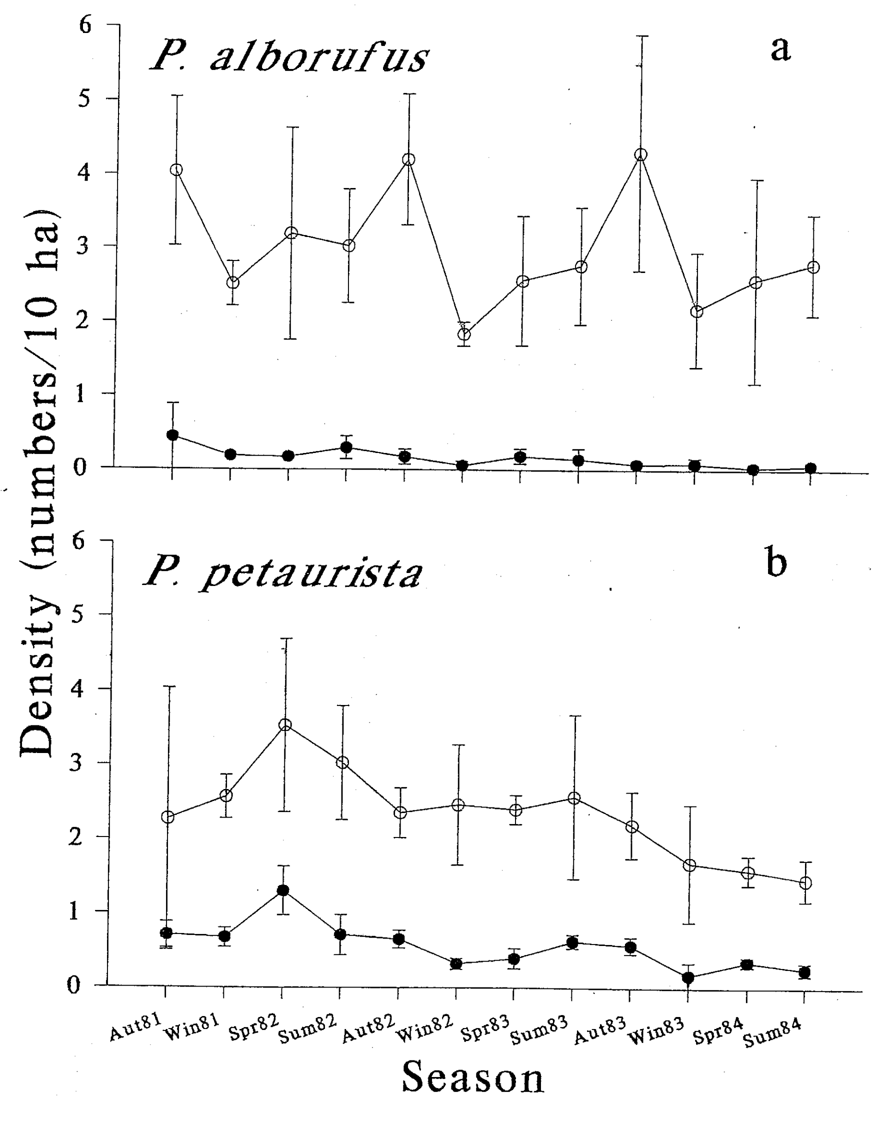

Fig. 1. Seasonal population trends (squirrels/10 ha, $\bar{x} \pm SE$) in conifer plantations (closed circles) and hardwood forests (open circles) for (a) *Petaurista alborufus* and (b) *P. petaurista* from October, 1981 to August, 1984 in Chitou, Taiwan.

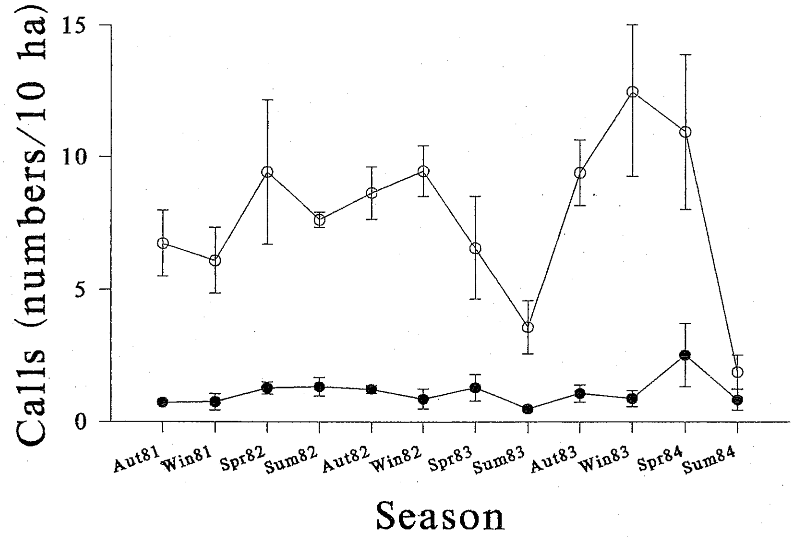

Fig. 2. Seasonal call indexes (squirrels/10 ha, $\overline{x} \pm$ SE) for *Petaurista alborufus* (open circles) and *P. petaurista* (closed circles) from October, 1981 to August, 1984 in Chitou, Taiwan.

The number of recorded calls for both species reveal a distinct difference (Fig. 2). *P. alborufus* called about six times more frequently than did *P. petaurista* (monthly average, 7.8 vs. 1.1 per 10 ha). Monthly count indexes for both species did not correlate with observed densities ($p > 0.05$). Average call indexes ($\pm$ SE) during fall, winter, spring, and summer were 1.0 (0.15), 0.9 (0.04), 1.7 (0.41), and 0.9 (0.24) for *P. petaurista,* respectively, and 8.3 (0.79), 9.3 (1.82), 9.0 (1.27), and 4.4 (1.71) for *P. alborufus,* respectively.

P. petaurista densities observed in hardwood forests were positively correlated with *P. alborufus* densities in the same habitat; no correlations were found in other situations. No significant correlation was found between squirrel densities and environmental variables ($p > 0.05$ for all cases).

DISCUSSION

Field methods for studying flying squirrels are limited (Weigl and Osgood 1974). It is particularly difficult to study giant flying squirrels because their arboreal nature makes it difficult to capture them in the field (Muul and Lim 1978, Lee *et al.* 1986). We attempted to trap squirrels with specially designed wire traps, but we had no success. The inexpensive and convenient spotlight counting method provides an attractive alternative for investigating the ecology of these squirrels. This method has also been applied to other nocturnal animal studies, such as the movements and population trends of white tailed deer (Progulske and Duerre 1964, McCullough 1982) and the population densities of brown hares (*Lepus capensis*) (Barnes and Tapper 1985). The squirrels in our study appeared undisturbed by the spotlights, and behaved normally unless being observed from a distance of less than 5 m (Lee *et al.* 1986). Lin *et al.* (1988) used a similar method to study the behavior and activity patterns of *P. petaurista* in Chitou, and mapped the home ranges of two *P. petaurista* individuals living in a conifer plantation. In general, the results we obtained were quite satisfactory, since these animals are generally difficult to find in daytime, and their eyeshine makes them easy to see with a spotlight (Barnes and Tapper 1985).

There were two specific difficulties we encountered in estimating population densities during this study. First, the steep topography and tall trees of the study sites made distance measurements impossible which prevented us from applying more advanced statistical methods such as those reviewed by Seber (1986). The second was that the ages and sexes of the squirrels were not easily identified in the field, especially since the squirrels were observed at a distance and our observations could only be made along established trails due to the dense understory of the study areas. Ideally, mark and recapture methods should be used in conjunction with spotlight observations (MacKinnon 1978).

Call counts are valuable indexes of population densities when conditions make it difficult to count animals directly (Davis and Winstead 1980); however, they may generate unreliable, misleading results as we previously stated, our call counts did not correlate with numbers of observed squirrels. One primary reason for this is that it is impossible to estimate the number of calls per individual. Animal behavior in a particular season (such as period of increased reproduction and territory defense) may affect the number of calls emitted by the squirrels. Despite these drawbacks, calls can be used to identify the presence of a squirrel species at nighttime, as both species have distinct vocalizations. At best, counts provide rough estimates of squirrel densities.

Both species showed strong preferences for hardwood forest habitat, but they differed in degree of habitat usage. *P. alborufus* was more restricted to hardwood forests, whereas *P. petaurista* exploited conifer plantations to a higher degree. *P. petaurista* is apparently better adapted to disturbed habitats such as conifer plantations than is *P. alborufus,* as the density of the former in conifer plantations was significantly higher than the latter. Such an adaptation by *P. petaurista* is possible because conifer plantations provide not only food sources (Lin and Lee 1986), but also resting sites and nesting materials (Lee *et al.* 1986, Lin *et al.* 1988). Most natural *P. petaurista* habitats have been converted to plantations, whereas the hardwood habitat favored by *P. alborufus* has been maintained under more natural conditions.

Giant flying squirrels are susceptible to habitat destruction (i.e., forest clear-cutting) since they heavily rely on tall forest trees for both nesting and feeding (Lee *et al.* 1986). It is not clear how hunting affects squirrel population trends. Given their low reproductive and population turnover rates (Lee *et al.* in press), and the population densities observed in this study, squirrel populations may not be able to maintain themselves under severe hunting pressure if their natural habitats are reduced to very small sizes. Further study on this hypothesis should be conducted.

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以夜間探照燈方式研究同地共存之大型鼯鼠族群量

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本研究利用夜間探照射搜尋方式，了解溪頭地區同地共存之大赤鼯鼠與白面鼯鼠的族群動態，研究期間從 1981 年 10 月，至 1984 年 8 月，共 107 晚，觀察到 298 隻大赤鼯鼠(115：183，針葉林：天然林)與 281 隻白面鼯鼠(32：249，針葉林：天然林)，以及 2,722 叫聲(337：2,385，大赤鼯鼠：白面鼯鼠)。二種鼯鼠在天然林之每月平均密度均高於其在針葉林內；而在天然林內，大赤鼯鼠與白面鼯鼠之平均密度相似，但在針葉林內，前者遠多於後者。白面鼯鼠在天然林內之族群，呈季節性變化，以秋季較高(平均＝4.2隻／10公頃，標準機差＝0.02)，冬季較低(平均＝2.1隻／10公頃，標準機差＝0.06)；而大赤鼯鼠則無此現象。二種鼯鼠在天然林之月平均密度呈正相關，但是其他情況則無，叫聲指標與族群密度也無相關性。大赤鼯鼠和白面鼯鼠在其天然棲息地內可以維持族群，但前者要比後者更能適應人爲的針葉林環境。

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Development and energy content of a brackish-water copepod, *Apocyclops royi* (Lindberg) reared in a laboratory[1]

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Wen-Been Chang and Chi-Hsiang Lei (1993) Development and energy content of a brackish-water copepod, *Apocyclops royi* (Lindberg) reared in a laboratory. *Bull. Inst. Zool., Academia Sinica* **32**(1): 62-81. The cyclopoid copepod *Apocyclops royi* produced six nauplius, five copepodite instars, and an adult stage when reared in a laboratory under 25°C, 30°/oo salinity, and with excess food resources. The durations of all nauplius were short and nearly isochronal beyond the copepodid I stage. Generation length was sixteen days. Regression equations for prosome length (P.L.) and body length (B.L.) vs. dry weight (D.W.), plus ash free dry weight (AFDW) were expressed as follows:

a). Nauplii:

ln (D.W.) = 1.0128 ln (B.L.) - 2.633 (R^2 = 0.768)

ln (AFDW) = 1.1771 ln (B.L.) - 3.120 (R^2 = 0.756)

b). Copepodites and Adults:

ln (D.W.) = 1.5289 ln (P.L.) - 3.876 (R^2 = 0.964)

ln (AFDW) = 0.9255 ln (P.L.) - 2.445 (R^2 = 0.891)

ln (D.W.) = 1.2924 ln (B.L.) - 3.504 (R^2 = 0.978)

ln (AFDW) = 0.7821 ln (B.L.) - 2.220 (R^2 = 0.903)

The mean ash content of this species was 2.47%, and the mean energy content of later copepodite stages was 5.13 cal/mg D.W. or 5.33 cal/mg AFDW.

Key words: *Apocyclops royi,* developmental stages, Laboratory rearing, Energy content, Brackish-water copepod.

Apocyclops royi (Lindberg) is a newly-recorded cyclopoid copepod species found in the Tan-Shui River estuary and brackish-water shrimp ponds in I-Lan and Tainan, Taiwan (Chang et al., 1991). The pecies has also been reported in freshwater regions of mainland China by Tai and Chen (1979). Adult and later copepodite stages of *A. royi* feed on the eggs and gravid segments of the cestode *Hymenolepis gracilis* (see Su and Lin, 1985) and nauplii of artemia (pers. obs.). In the Tan-Shui River estuary, this pecies occurs commonly and subdominantly year-round in zooplankton.

It is important to accurately estimate biomass and production for predator-prey interactions in aquatic ecosystems (Chisholm and Roff, 1990). Copepods generally dominate metazoan zooplankton both in abun-

1. Paper No. 371 of the Journal Series of the Institute of Zoology, Academia Sinica.
2. Dr. Lei passed away on September 12, 1990.