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**Short communication**

# Preliminary estimation of population density of the Siberian flying squirrel (*Pteromys volans orii*) in natural forest of Hokkaido, Japan

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The Siberian flying squirrel *Pteromys volans* is widely distributed from northern Finland east to Chukotka of Russia; south to the eastern Baltic shore and across the southern Ural Mountains and Altai Mountains of Russia to Mongolia, northern China, Korea, Sakhalin Island of Russia, and Hokkaido Island of Japan (Nowak 1991; Wilson and Reeder 2005). This squirrel is arboreal and inhabits the boreal evergreen forests of the Eurasian Continent (e.g., Nowak 1991). It nests in tree cavities (Yanagawa 1999; Yanagawa and Muraki 2006; Asari and Yanagawa 2008; Asari et al. 2009; Nakama and Yanagawa 2009). *Pteromys volans orii*, a subspecies endemic to Hokkaido Island, Japan, is common from lowlands to mountainous areas (Kuroda 1921; Ishii 2005; Oshida 2009). Ecological characteristics of this subspecies in fragmented forests, small forests, and windbreak forests in urban or agricultural areas are already reported (Yamaguchi and Yanagawa 1995; Yanagawa 1999; Asari et al. 2008, 2009; Tojo and Yanagawa 2008). We, however, doubt these characteristics are original. They may have been influenced by human activities in these semi-artificial environments. To understand the original ecological characteristics of *P. volans orii*, we need to investigate this subspecies in its original habitats, such as the natural and mountainous forests in Hokkaido. There are only a few reports on the ecological characteristics of *P. volans orii* in mountainous natural forests (Nakano et al. 1991; Masuda 2003).

The vegetation of Hokkaido's natural forests mainly consists of *Abies sachalinensis*, *Picea jezoensis*, *Quercus mongolica*, *Betula* spp., and *Tilia japonica* (Tatewaki 1958; Horikawa 1972; Okitsu 2002). This is quite different from forests of northern Eurasia where *P. volans* occurs. Of these tree species, *Abies sachalinensis* is confined to Hokkaido Island, southern parts of Sakhalin Island, and the Kuril Islands (Satake 1989), but is most abundant in Hokkaido's natural forests. We expected to find an ecological association between *P. volans orii* and *A. sachalinensis*. As a first step understanding the ecological characteristics of *P. volans orii*, we selected a large *A. sachalinensis*-dominated mixed forest for preliminary examination of the population density of this subspecies by capture-mark-recapture methods using wooden nest boxes. Nest boxes are often used in ecological studies of flying squirrels in the Holarctic region (e.g., Raymond and Layne 1988; Layne and Raymond 1994; Hanski et al. 2000; Taulman and Smith 2004). Because the animals are not strongly attracted by bait, nest boxes are more suitable for estimating the population density of those arboreal small mammals (Fokidis and Risch 2005). Here, we discuss preliminary population density estimates for *P. volans orii* in the natural forest of Hokkaido.

## Methods

*Study area and site*

This study was conducted in the University Forest in Hokkaido, The University of Tokyo, Furano, Hokkaido, Japan (43°10–20'N, 142°20–40'E, Fig. 1). This natural forest has an area of 22,894 ha. It is characterized with natural sub-arctic mixed forests. Dominant stands are *Abies sachalinensis*, *Tilia japonica*, *Acer mono*, and *Picea jezoensis* (Yamamoto et al. 1995). In this forest, we chose a 5.4 ha area dominated by *Abies sachalinensis* as our study site.

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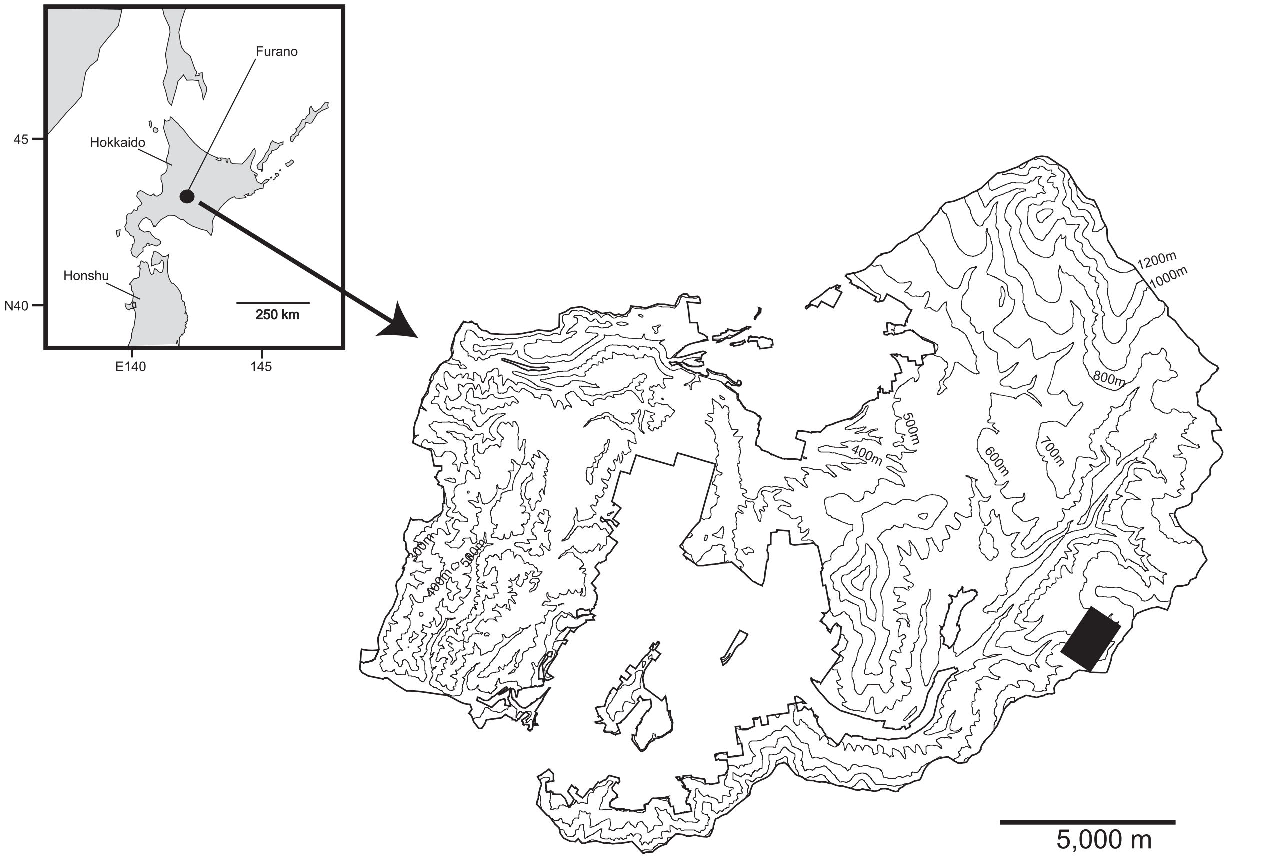


**Fig. 1.** Study area (University Forest in Hokkaido, The University of Tokyo in Furano, Japan) covered with *Abies sachalinensis*-dominated mixed forest. Solid square shows study site where we set 60 nest boxes.

*Trapping and marking of animals*

Following methods of Yanagawa (1994), we built wooden nest boxes with inside dimensions of 11 cm by 16 cm by 20 cm. Entrance dimensions were 4 cm by 4 cm. In May 2009, 60 nest boxes were attached to trees at heights of 3 m. We made three transects in study site, and placed 20 nest boxes along each transect at 20–30 m-intervals. We did not establish tree species and bearings for these nest boxes. Distances between lines were around 30 m. Each month, from May to October 2009, we checked all nest boxes in daytime. During winter (from November to early March), 3–5 individuals may share a single nest cavity (Yanagawa 1999). As the nesting pattern in winter is quite different from that in spring, summer, and autumn, our method of using nest boxes to census the population is not applicable during winter. Therefore, we did not include data on population size in winter and early spring. Captured flying squirrels were weighed and ear-tagged. Ear tags were 2.5 mm by 6.0 mm (KN-295-A, Natsume Seisakushyo Co., Ltd). Nestlings too small to be ear-tagged were not marked. We recorded sex and age of adult and sub-adult animals. Age classes were based on body weight: adults were ≥100 g and sub-adults were <100 g. Yamaguchi and Yanagawa (1995) report that almost sub-adults were <90 g. We regarded 100 g as a suitable border to discriminate between adults and sub-adults. We returned each animal into its nest box and returned the nest box to its original place. We also recorded presence of nest materials.

*Data analyses*

We calculated the Lincoln index (*LI*, Le Cren 1965) of each month on the basis of capture-mark-recapture results where: *LI* = number marked in that sample/total caught in that sample. Also, we estimated population size as: number of individuals = number of captured individuals at that month × accumulative number of marked individuals until that month/number of marked individuals among individuals captured in that month. These calculations are used to estimate the size of closed populations (e.g., Seber 1982), although our study site is not closed. In addition, seasonal change of *P. volans orii* population

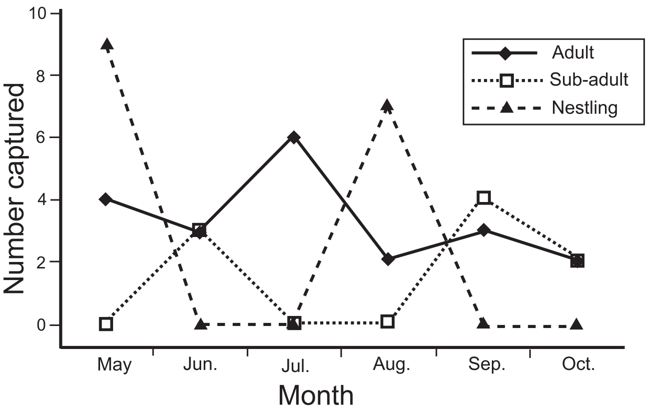


**Fig. 2.** Numbers of *Pteromys volans orii* captured from May to October 2009 in a 5.4 ha *Abies sachalinensis*-dominated mixed forest in Hokkaido, Japan. Ages are categorized as three classes: adult, subadult, and nestling.

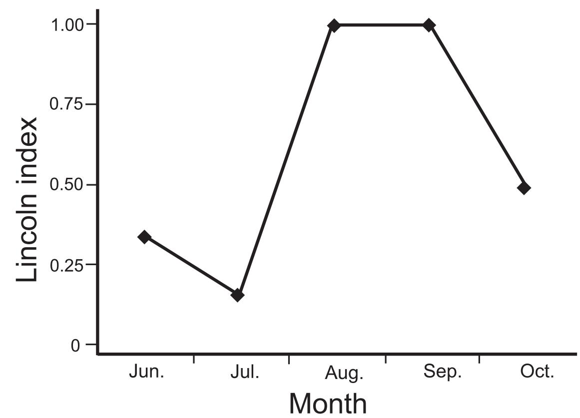


**Fig. 3.** Seasonal change in Lincoln index of each month calculated from June to October 2009 for adults of *Pteromys volans orii* in an *Abies sachalinensis*-dominated mixed forest in Hokkaido, Japan.

size is affected by changes in number of sub-adults and nestlings. Each *P. volans* individual, however, has a different home range (e.g., Hanski et al. 2000; Reunanen et al. 2002) and adults individuals show high site fidelity (Hanski et al. 2000). Therefore, we attempted to estimate population size for adults only in the month that is probably thought to have most stable adult number.

## Results and discussion

*Captured flying squirrels*

Of 360 checks of nest boxes during the six months, boxes were occupied by *P. volans orii* 78 times. Of the 60 nest boxes, 38 were used. We captured a total of 40 individuals: 12 adults (6 males and 6 females), 9 sub-adults (7 males and 2 females), and 16 nestlings (unidentified sex) (Fig. 2). Five of the 16 nestlings eventually became 5 of 9 sub-adults. The 21 animals (12 adults and 9 sub-adults) were marked and released. Adults were found in each month. Sub-adults were found in June, September, and October (Fig. 2). Nestlings were observed in May and August (Fig. 2). Therefore, nestlings born on May and August could have been found as sub-adults in June and September, respectively. In July 6 adults were captured, however, 5 of them were newly marked. This may suggest that the animals born on May became almost adults in the study site, and/or some young animals immigrated from different areas. These reproductive ecological futures of *P. volans orii* are also reported in urban or agricultural areas (Yanagawa 1999). Judging from these findings, we expected that adult number could be most stable in August.

*Estimation of population density*

The highest *LI* (1.0) was maintained in the adults for August and September (Fig. 3). The *LI* increased from June to August, decreasing in October (Fig. 3). Population size (N) was estimated to 11 for adults in August. Based on this number, the population density in the *Abies sachalinensis*-dominated mixed forest in our study area was calculated as 2 individuals/ha. Population densities of the northern flying squirrel (*Glaucomys sabrinus*) in boreal and sub-arctic forests are estimated as 0.2–1.8 individuals/ha in *Populus*-dominated forest; 1.2–5.8 individuals/ha in *Abies*-dominated forest; 0.2–2.1 individuals/ha in *Picea*-dominated forest (Anderson et al. 1980), 0.5–1.3 individuals/ha in *Pseudotsuga menziesii*-dominated old growth forest (Witt 1992), and 2 individuals/ha in the *Pseudotsuga menziesii*-dominated old growth and second growth forests (Rosenberg and Anthony 1992), and 2–3 individuals/ha in *Abies*-dominated old growth forest (Waters and Zabel 1995). These values are similar to our estimates here. Therefore, population sizes of flying squirrels occurring in boreal and sub-arctic forests may be restricted by similar environmental forces. In Finland, however, the density of female *P. volans* was estimated as 0.65/km$^2$ in 1981 and 0.43/km$^2$ in 1998 (Sulkava et al. 2008). Based on captures and radio-tracking data, Hanski et al. (2000) also reported densities of *P. volans* as 0.04/ha and 0.08/ha in southern Finland. These values are much less than our estimates. There should be a difference in densities between the Hokkaido and Finland populations, because *P. volans* is categorized as vulnerable in Finland (Rassi et al. 2001).

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