Russian J. Theriol. 9(1): 39–43

Cavity resources for Siberian flying squirrel, *Pteromys volans orii*, in two different habitats in Hokkaido, Japan

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ABSTRACT. The Siberian flying squirrel (*Pteromys volans*) is arboreal and usually nests in cavities in trunks. The population on Hokkaido Island, Japan, is considered an endemic subspecies (*P. volans orii*). In mountainous areas of Hokkaido, *P. volans orii* mainly inhabits mixed forests dominated by *Picea jezoensis* or *Abies sachalinensis*. To understand these usefulness as *P. volans orii* habitat, we made a preliminary comparison of cavity resources in two different forests common in Hokkaido. Inner space of cavities in *A. sachalinensis*-dominated habitat was significantly larger than that in *P. jezoensis*-dominated habitat. This may mean that *A. sachalinensis*-dominated habitat provides more useful cavity nests for *P. volans orii*. *Abies sachalinensis* is only distributed in Hokkaido and Sakhalin Island and the Kuril Islands of Russia. *Pteromys volans orii* might have adapted itself into the unique *A. sachalinensis*-dominated forests located on the periphery of *P. volans* distribution.

KEY WORDS: *Pteromys volans*, *Picea jezoensis*, *Abies sachalinensis*, mixed forest.

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Ресурсы дупел для сибирской летяги, *Pteromys volans orii*, в двух различных местообитаниях на Хоккайдо, Япония

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РЕЗЮМЕ. Сибирская летяга (*Pteromys volans*) обычно устраивает гнезда в дуплах деревьев. Популяция острова Хоккайдо, Япония, рассматривается в качестве эндемичного подвида (*P. volans orii*). В горных районах Хоккайдо *P. volans orii* населяет преимущественно смешанные леса с доминированием *Picea jezoensis* или *Abies sachalinensis*. Для оценки пригодности этих местообитаний для *P. volans orii* было проведено предварительное сравнение ресурсов дупел в двух различных типах лесов, встречающихся на Хоккайдо. Внутреннее пространство дупел в лесах с доминированием *A. sachalinensis* оказалось значительно крупнее, чем в лесах с доминированием *P. jezoensis*. По-видимому, местообитания с доминированием *A. sachalinensis* более привлекательны для создания гнездовых камер *P. volans orii*. Пихта *Abies sachalinensis* распространена только на Хоккайдо в Японии и на острове Сахалин и Курильских островах в России. Периферический подвид летяги *Pteromys volans orii* может быть приспособлен к уникальным лесам с доминированием *A. sachalinensis*.

КЛЮЧЕВЫЕ СЛОВА: *Pteromys volans*, *Picea jezoensis*, *Abies sachalinensis*, смешанные леса.

Introduction

Of all flying squirrel species, *Pteromys volans* (Siberian flying squirrel) has a widest distribution range and occurs in Palearctic taiga (Wilson & Reeder, 2005). Ognev (1966) described this species as inhabiting spruce (*Picea abies*)-dominated boreal forests from Finland to eastern Siberia. In Finland, this species prefers spruce-dominated mixed forests with deciduous trees for food and large aspens (*Populus tremula*) for nest cavity trees (Hanski, 1998; Reunanen *et al*., 2002). In Leningrad, Vologda, and Novgorod provinces, Russia, this species also inhabits mixed forests dominated by conifers and hardwoods such as aspens, birchs, alders, and willows (Novikov *et al*., 1970).

The Hokkaido population of Siberian flying squirrel is regarded as an endemic subspecies *P. volans orii* (Kuroda, 1921). Phylogeographically, it separated early from the Eurasian populations (Oshida *et al*., 2005). In the mountainous areas of Hokkaido, *P. volans* mainly inhabits mixed forests dominated by *Picea jezoensis* or *Abies sachalinensis* (Nakano *et al*., 1991). Both *Picea jezoensis* and *Abies sachalinensis* are dominant conifers in the mountainous natural forests of Hok-

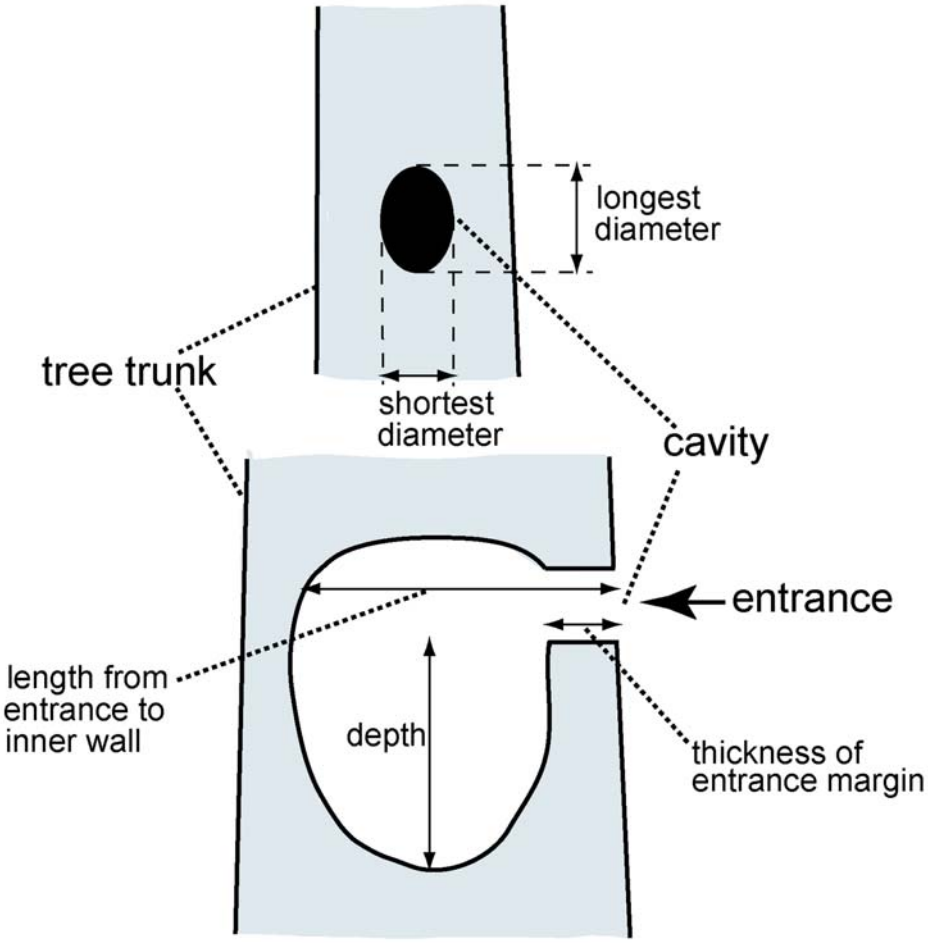

Fig. 1. Measurements used to describe tree cavities according to Masuda (2003).

kaido. *Picea jezoensis* is distributed in northeastern Russia (Kuril Islands, Sakhalin, Primorskii, and Kamchatka Peninsula), Korean Peninsula, northeastern China, and Hokkaido. *Abies sachalinensis* is found only in Hokkaido, the southern part of Sakhalin, and Kuril Island (Satake, 1989). Therefore, the forest habitats of *P. volans orii* in Hokkaido are quite different from typical forest habitats in the Eurasian Continent. Since *P. volans* inhabits spruce-dominated mixed forests in Eurasia (Ognev, 1966), we may be able to expect that this flying squirrel prefers the *P. jezoensis*-dominated forest habitat in Hokkaido instead of the *A. sachalinensis*-dominated forest.

In Eurasia, *P. volans* usually uses tree cavities as nests (Airapetyants & Fokin, 2003), although they are sometimes known to build dreys (Hanski, 1998; Hanski *et al*., 2000). Also, in Hokkaido, *P. volans orii* usually uses cavities as nests (Nakano *et al*., 1991; Yanagawa, 1999; Masuda, 2003). To understand habitat preference of *P. volans orii* in Hokkaido, the abundance of cavities could be reasonable and analyzable indicator.

In the present study, as a first step forwards identifying habitat preference of *P. volans orii*, we simply compared cavity resources between two different natural forest habitats in Hokkaido: *P. jezoensis*-dominated and *A. sachalinensis*-dominated mixed forests. We discuss which habitat has more abundant nest resource for *P. volans orii*.

Study Area

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). This natural forest has an area of 22,894 ha and is covered with natural sub-arctic mixed forests. Its dominant stands are *Abies sachalinensis*, *Tilia japonica*, *Acer mono*, and *Picea jezoensis* (Yamamoto *et al*., 1995).

Methods

We surveyed nest cavities from May to October 2008 in 5 *A. sachalinensis*-dominated 1-ha plots and 5 *P. jezoensis*-dominated 1-ha plots. We concentrated on locating cavities < 4 m above the ground because it was

difficult and dangerous to check for cavities located higher up the tree. Cavity trees were described by species, height, diameter at breast height (DBH), diameter at cavity height (DCH), and type (living or snag). We characterized each cavity in each tree with 6 measurements following Masuda (2003): height above ground, longest diameter, shortest diameter, thickness of entrance margin, length from entrance to inner wall, and depth (Fig. 1). We also checked whether they were used by *P. volans orii*. We used a Mann-Whitney *U*-test to compare cavity trees and cavities between the two forest types.

Results

We found a total of 45 cavities on 44 trees in the *A. sachalinensis*-dominated 1-ha plots and 57 cavities on 47 trees in *P. jezoensis*-dominated 1-ha plots. In the *A. sachalinensis*-dominated habitat, most cavities were in trunks of *A. sachalinensis*. In the *P. jezoensis*-dominated habitat, cavities were mainly on *P. jezoensis* and *A. sachalinensis* (Table 1). In the *A. sachalinensis*-dominated habitat, cavities were on 32 live trees and 13 snags. In the *P. jezoensis*-dominated habitat, cavities were on 39 live trees and 8 snags. Between habitats,

Table 1. Cavity tree species in two different habitats of *Pteromys volans orii.*

Species	Number (%) of cavity trees in habitats	
	A. sachalinensis-dominated	*P. jezoensis*-dominated
Abies sachalinensis	22 (50.00)	12 (25.53)
Picea jezoensis	1 (2.27)	15 (31.92)
Taxus cuspidata	1 (2.27)	0
Magnolia obovata	1 (2.27)	0
Padus ssiori	0	1 (2.13)
Sorbus commixta	2 (4.55)	3 (6.38)
Phellodendron amurense	2 (4.55)	0
Acer mono	3 (6.82)	2 (4.26)
Acer spp.	7 (15.91)	5 (10.64)
Tilia japonica	2 (4.55)	2 (4.26)
Tilia maximowicziana	2 (4.55)	0
Fraxinus mandshurica	0	1 (2.13)
Acer ukurunduense	0	4 (8.51)
Betula ermanii	0	2 (4.26)
unknown	1 (2.27)	0
Total	44	47

Table 2. Comparison of mean measurements (SD in parentheses) of cavity trees and cavities between two different *Pteromys volans orii* habitats; we concentrated on locating cavities < 4 m above the ground.

Variable	Habitat		*P**
	A. sachalinensis-dominated	*P. jezoensis*- dominated	
Cavity trees			
Height (m)	19.01 (7.92), n=33	18.29 (8.23), n=39	0.71
DBH (cm)	34.54 (17.87), n=41	43.75 (26.30), n=47	0.12
DCH (cm)	45.81 (38.65), n=44	45.54 (27.84), n=52	0.41
Cavities			
Height above ground (m)	1.29 (0.75), n=45	1.50 (0.81), n=57	0.14
Longest diameter (cm)	15.16 (12.52), n=45	12.29 (10.96), n=57	0.12
Shortest diameter (cm)	4.90 (3.06), n=45	5.16 (3.16), n=57	0.72
Thickness of entrance margin (cm)	2.55 (2.52), n=45	1.03 (2.04), n=57	< 0.01
Length from entrance to inner wall (cm)	14.24 (33.34), n=45	2.30 (4.72), n=57	< 0.01
Depth (cm)	12.73 (8.62), n=45	11.22 (7.46), n=57	0.40

*Mann-Whitney's *U*-test

cavity trees did not significantly differ in height, DBH, and DCH ($P > 0.05$, Table 2). The cavities also did not differ in height above ground, longest diameter, shortest diameter, and length from entrance to inner wall ($P > 0.05$). Thickness of entrance margin and depth were significantly greater in the *A. sachalinensis*-dominated habitat than in the *P. jezoensis*-dominated habitat ($P < 0.01$) (Table 2). Only 4 cavities in live trees were used by *P. volans orii* in the *A. sachalinensis*-dominated habitat. No cavities were used in the *P. jezoensis*-dominated habitat.

Discussion

Number of cavities found in the *A. sachalinensis*-dominated habitat was similar to that in the *P. jezoensis*-dominated habitat, showing cavity resources were similar in these two different habitats. In the *A. sachalinensis*-dominated habitat, 50% of cavities were found on *A. sachalinensis*. Even in the *P. jezoensis*-dominated habitat, 25% of cavities were on *A. sachalinensis*, although the most cavity abundant tree was *P. jezoensis* (31.92% of total number). *Pteromys volans orii* may find *A. sachalinensis* more useful in nesting. In fact, *P. volans orii* most frequently nests in *A. sachalinensis* in northern Hokkaido (52.80%; Nakano *et al*., 1991) and eastern Hokkaido (33.33%; Masuda, 2003). *Pteromys volans orii* may have more opportunity to nest *A. sachalinensis* because it had the most cavities.

Between two different habitats, cavity trees did not differ in most measurements (Table 2), showing that the similar sized trees have cavities. Thickness of entrance margin and the cavity depth were significantly greater in the *A. sachalinensis*-dominated habitat than in the *P. jezoensis*-dominated habitat (Table 2). Cavities in the *A. sachalinensis*-dominated habitat may have tougher entrance and wider interior space than those in the *P. jezoensis*-dominated habitat. Nakano *et al*. (1991) reported that the nest space of *P. volans orii* was 18 x 18 x 56 cm in northern Hokkaido. Masuda (2003) showed that nest depth was 27.5 cm. Therefore, wider interior space could be important for nesting of *P. volans orii*. This may mean that *A. sachalinensis*-dominated habitat provides more useful cavity nests for *P. volans orii*. Unfortunately, it is difficult to identify why thickness of entrance margin and depth differed between two habitats. Further studies should examine the relationship between these two cavity measurements and how the cavities are made.

We found *P. volans orii* using only four cavities in the *A. sachalinensis*-dominated habitat and none in the *P. jezoensis*-dominated habitat. Our data, however, are insufficient to state that *P. volans orii* prefers the *A. sachalinensis*-dominated habitat to the *P. jezoensis*-dominated habitat. Of the four cavities used by *P. volans orii*, all were on live trees. Masuda (2003) and Asari *et al*. (2009) reported that *P. volans orii* nested more in live trees than snags. Our finding also may support these previous reports, but it was not conclusive due to few data. The *A. sachalinensis*-dominated habitat may provide more useful nest resources for *P. volans orii* than the *P. jezoensis*-dominated habitat. This endemic flying squirrel subspecies might have successfully adapted itself to the unique *A. sachalinensis*-dominated forests located on the periphery of the *P. volans* distribution. To further understand the habitat preference of *P. volans orii*, however, food resources must be considered. *Pteromys volans orii* may preferentially use food resources in *A. sachalinensis* habitat or in *P. jezoensisi* habitat. Information of both nest and food resource preferences may clarify the habitat preference of *P. volans orii*.

ACKNOWLEDGEMENTS

We appreciate the support and field assistance provided by Y. Igarashi, A. Kato, K. Ishii, M. Noda, M. Matsuhashi, R. Haraguchi, S. Sato, Y. Kondo, K. Akashi, Y. Nojima, K. Washinosu, K. Ono, and A. Ieiri. We thank H. Yanagawa and Y. Konno for helpful comments. We are grateful to C. L. Bridgman for her critical reading of the manuscript. This study was partially supported by the Grant-in-Aid for Scientific Research No. 21380086 from the Ministry of Education, Science, Sports, and Culture, Japan.

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