Published by Associazione Teriologica Italiana
Volume 24 (2): 187–189, 2013
Hystrix, the Italian Journal of Mammalogy

Available online at:
http://www.italian-journal-of-mammalogy.it/article/view/8975/pdf
doi:10.4404/hystrix-24.2-8975

Research Article

Nest cavity selection by the Siberian flying squirrel *Pteromys volans*

Kei Suzuki[a,b,*], Mayu Sagawa[b], Hisashi Yanagawa[a,b]

[a] *The United Graduate School of Agricultural Sciences, Iwate University, Morioka 020-8550, Japan*
[b] *Laboratory of Wildlife Ecology, Obihiro University of Agriculture and Veterinary Medicine, Obihiro 080-8555, Japan*

Keywords:
nest site selection
population decline
predator avoidance
Siberian flying squirrel
tree cavity

Article history:
Received: 27 June 2013
Accepted: 6 November 2013

Acknowledgements
We are grateful to Drs. I. Koizumi, T. Aoi, T. Oshida, and M.B. Takada for their helpful comments concerning this study. Suggestions from anonymous reviewers were helpful in improving the manuscript. This study was financially supported by the Inui Memorial Trust for Research on Animal Science.

Abstract

Populations of the Siberian flying squirrel *Pteromys volans* are declining as a result of intensive forestry that has removed cavity trees. To conserve the cavities preferred by squirrels, we investigated the characteristics of the cavities they used as nests. We located 100 cavities with >3.0 cm entrance size (which they are able to enter), and investigated their use by squirrels. We also recorded the entrance height and size of the cavities and the health and height of cavity trees. The squirrels used 29 of 100 cavities. Entrance size and tree health strongly influenced cavity use, and entrance height had a weaker influence. Tree height was not correlated with cavity use. Squirrels preferred higher cavities with smaller entrances and on live trees. The entrance size of cavities used was $\leq$5.0 cm. Squirrels used 38% of live trees but only 14% of dead trees. In addition, squirrels never used cavities <1.0 m above the ground. Hence, cavities at >1.0 m height and with entrance sizes of 3.0 to $\leq$5.0 cm on live trees were preferred. We suggest that trees with these cavity characteristics should be conserved during felling operations to protect important habitat futures for Siberian flying squirrels.

Introduction

Tree cavities are important nest sites for gliding mammals such as flying squirrels (e.g. Taulman 1999; Holloway and Malcolm 2007) and gliding marsupials (e.g. Traill and Lill 1997; Lindenmayer 2002). The Siberian flying squirrel (*Pteromys volans*) depends on such cavities (Hanski et al., 2000b; Suzuki and Yanagawa, 2012). In Finland, Estonia, and Korea, populations of this squirrel have declined (Hokkanen et al., 1982; Won and Smith, 1999; Lampila et al., 2009; Selonen et al., 2010; Santangeli et al., 2013) as a result of intensive forestry that has removed cavity trees (Jackson, 2012). Habitat management aimed at conserving tree cavities may be needed to conserve the squirrels, and those cavities and cavity trees that they selectively use should be preferentially conserved. However, little is known about their preferences (Kadoya et al., 2010). Therefore, to promote the conservation of cavities and cavity trees preferred by this species, we examined its nest cavity selections.

Cavity-nesting animals have evolved adaptations of nest-site selection to avoid predation (Martin, 1998), which is the cause of nest losses (Li and Martin, 1991; Mitrus and Socko, 2008). Cavity height, entrance size, and condition of cavity trees are especially important factors for predator avoidance. To decrease predation risks, these animals therefore select high cavities (Wesolowski, 2002; Mitrus and Socko, 2008; Kosinski et al., 2011) with small entrances (Ruczynski and Bogdanowicz, 2005) and in live trees (Wesolowski, 2002).

Gliding which is an important ecological characteristic of flying squirrels may influence cavity selection. The energy cost of gliding transport decreases with increasing glide distance (Scheibe et al., 2006; Flaherty et al., 2008). To glide long distances, Siberian flying squirrels launch from tall trees (Suzuki et al., 2012). If the squirrels nest in cavities on trunks of tall trees, they can easily glide long distances. Consequently, they may prefer cavities of tall trees as nest sites. To elucidate nest cavity selection by Siberian flying squirrels, we tested the following two hypotheses: (1) the predator hypothesis, i.e. to avoid predation, Siberian flying squirrels nest in higher cavities with small entrances on the trunks of live trees; and (2) the gliding hypothesis, i.e. to efficiently glide long distances, the squirrels nest in the cavities of tall trees.

Methods

Study areas

We surveyed tree cavities in forests in the Tokachi area (approximately 20 ha, 42°51' to 42°53' N, 143°09' to 143°11' E) of eastern Hokkaido, northern Japan; cavity use by Siberian flying squirrels has been found in this area (Suzuki and Yanagawa 2012). The surveyed forests chiefly comprised Korean pine (*Pinus koraiensis*), eastern white pine (*Pinus strobus*), Japanese larch (*Larix leptolepis*), Japanese white birch (*Betula platyphylla*), Manchurian walnut (*Juglans mandshurica*), and Japanese emperor oak (*Quercus dentata*). Tree density averaged 692 trees/ha (29% conifers, 71% broadleaves). Tree height averaged 15.3$\pm$5.6 (SD) m, and diameter at breast height averaged 26.0$\pm$11.3 cm (Suzuki et al., 2012).

Data collection and analysis

To explore the use of tree cavities by Siberian flying squirrels, we located 100 cavities with >3.0 cm entrance size, because the squirrels can pass through holes of this size (Airapetyants and Fokin, 2003). Sixty-four cavities were located on live trees and 36 on dead trees. From May to October 2012 we used the presence of feces, or video camera observation, to determine whether any of the cavities that we located had been used by Siberian flying squirrels. Each cavity was checked three times, once in each of three seasons, i.e. in spring (May to June), summer (July to August), and autumn (September to October), because the squirrels in the study areas use 2.6 cavities/individual during the snow-free period of the year (Asari and Yanagawa, 2007). If we found squirrel feces accumulated at the foot of a cavity tree, we placed an umbrella

*Corresponding author
Email address: pteromys@mail.goo.ne.jp (Kei Suzuki)

Table 1 – Summary of logistic regression analysis for nest cavity selection by Siberian flying squirrels.

Variables	Coefficient	SE
Entrance height	0.339	0.181
Entrance size	-0.800	0.380
Tree health	1.678	0.671
Tree height	0.015	0.048

upside down on the feces so as to collect any new feces, in accordance with the method of Suzuki et al. (2011). The next morning, if new feces were present in the umbrella, we considered that the cavity was being used by Siberian flying squirrels. If accumulated squirrel feces or new feces were absent, the cavity was considered to be unused (Suzuki et al., 2011). If a cavity was located >4 m above the ground, we used video camera (Sony HDR-CX520V, HDR-SR11, and HDR-SR12, Tokyo, Japan) observation, as accurate feces collection from such a height was difficult. Camera observation started 30 min before sunset and stopped 60 minutes after sunset on a single night (the time when the squirrels are most likely to leave their nests, Yamaguchi and Yanagawa 1995). If a flying squirrel was recorded leaving a cavity, then the cavity was considered to be used.

To elucidate cavity selection by Siberian flying squirrels, we recorded four environmental variables based on the predictions of our two hypotheses: (1) to test the predator hypothesis, the entrance height above the ground, minimum entrance size, and cavity tree health (dead or alive) were recorded; and (2) to test the gliding hypothesis, we recorded tree height. We used logistic regression to evaluate the influence of the above-described cavity and tree characteristics on nest cavity selection by Siberian flying squirrels. Cavity use by the squirrels was used as a dependent variable. For the dependent variable we replaced used/unused with 1/0 as a dummy variable in the analysis. We used entrance height, entrance size, tree health, and tree height as independent variables. The significance of each parameter was confirmed by checking whether residual deviance was significantly reduced when removing the parameter, using a χ^2 test.

Results

Siberian flying squirrels used 29 of the 100 tree cavities during the study period. Of the 29 tree cavities, 13 were used in spring (May to June), 11 in summer (July to August), and 9 in autumn (September to October). Only four of the 29 cavities were used twice (in spring and summer); the other 25 were used only once in the study period. The logistic regression (Tab. 1) revealed that entrance height, tree health, and tree height positively effected cavity selection. In contrast, entrance size had a negative effect. The result of the χ^2 test showed that entrance size (χ^2 = 5.80, p = 0.016) and tree health (χ^2 = 7.13, p = 0.008) strongly determined cavity use, while entrance height had a weaker, non significant influence (χ^2 = 3.67, p = 0.055). In contrast, tree height was unrelated to cavity use (χ^2 = 0.10, p = 0.75). Siberian flying squirrels frequently used cavities with smaller entrances (Fig. 1) or in live trees. Entrance size of the cavities used was limited to $\geq$5.0 cm. The squirrels used 38% (24/64) of live trees but only 14% (5/36) of dead trees. Used cavities (2.8$\pm$0.3 [SE] m; range: 1.0 to 9.0 m) were slightly higher than unused cavities (2.6$\pm$0.2 m; 0.4 to 6.7 m) (Fig. 2). Notably, the flying squirrels tended to avoid using cavities at low heights, and they never used cavities <1.0 m above the ground.

Discussion

Our results indicated that Siberian flying squirrels preferred higher cavities ($\geq$1 m above ground) with smaller entrance sizes ($\geq$5.0 cm) and in live trees (Tab. 1). Flying squirrels were already known to prefer small entrance cavities (Kadoya et al., 2010), but our study adds new information that they also prefer higher cavities in live trees. These selections support our predator hypothesis. In contrast, tree height had no significant effect on the squirrels' selection. Thus, the gliding hypothesis is rejected. Nest cavity and cavity tree selection by Siberian flying squirrels is therefore likely based on the need to decrease predation risk.

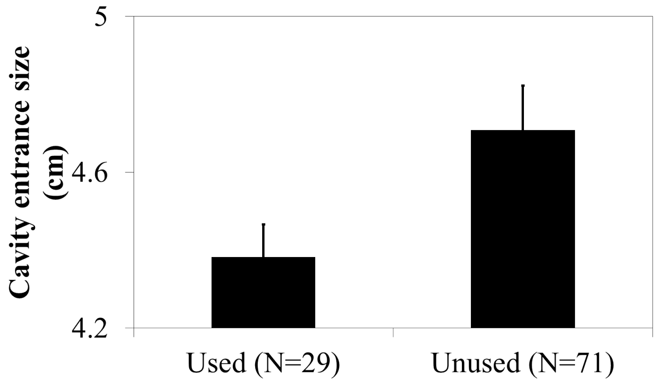

Figure 1 – Mean entrance sizes with SE (error bars) of used and unused cavity by Siberian flying squirrels.

Entrance size can affect the risk of predation by terrestrial carnivores. Entrance size of cavities used was less than $\leq$5.0 cm (Fig. 1). If a cavity has a large entrance, then raids by predators such as carnivores may be possible. The pine marten (*Martes martes*) and the sable (*Martes zibellina*), which are predators of this squirrel (Hanski et al., 2000a; Murakami, 2003), may find it difficult to pass through an entrance with a diameter of $\leq$5.0 cm, because their respective mean zygomatic widths are 4.4 cm (Reig and Ruprecht, 1989) and 4.0 cm (n = 20, unpublished data). The squirrels would therefore likely tend to avoid cavities with entrance sizes of more than approximately 5.0 cm to decrease predation risk.

Entrance height can also influence predation risk. Squirrels avoid nesting in cavities <1 m above the ground (Fig. 2). Use of high entrances reduces the risk of attack by terrestrial predators(Rendell and Robertson, 1989; Vonhof and Barclay, 1996; Forstmeier and Weiss, 2004). We suggest that using cavities $\geq$1 m high may help the squirrels to avoid nest attacks by carnivores that cannot climb trees, such as the red fox (*Vulpes vulpes*), a predator with a mean head and body length of 60 to 65 cm (Uraguchi, 2009).

Tree health, in contrast, may be related to risk of predation by avian predators. Owls are among the most important potential predators of Siberian flying squirrels (Hanski et al., 2000a). The Ural owl (*Strix uralensis*) is an important predator, and Siberian flying squirrels are practically absent in this owl's nesting areas (Byholm et al., 2012). We consider that squirrels in our study forests have likely been exposed to danger from Ural owls, that were breeding or at least present in this area in 2009, 2010 and 2012 (unpublished data). When squirrels leave their cavities, the cover provided by live trees may conceal them from the owls, which is not the case for cavities in dead trees.

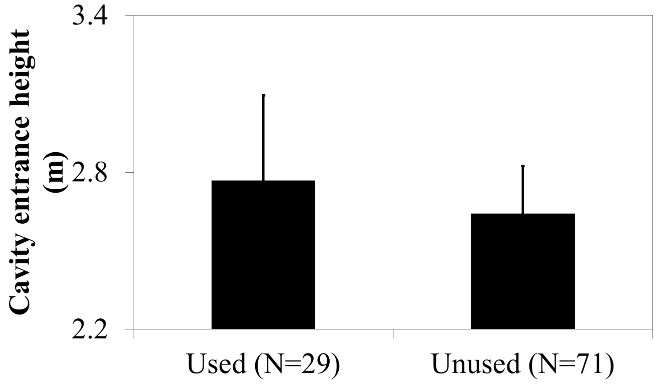

Figure 2 – Mean entrance heights with SE (error bars) of used and unused cavity by Siberian flying squirrels.

We suggest that secure cavities should be conserved to protect the habitat of Siberian flying squirrels, because the squirrels' choice of nesting cavities is related to their need to avoid predators. We believe that the threat from predators strongly affects nest cavity selection by flying squirrels, although we did not determine the relationship between nest characteristics and predation rate. This relationship needs to be explored further to elucidate the importance of these characteristics. If number of tree cavities preferred by this squirrels decline in their habitats, then nest boxes should be installed in accordance with the placement method of Suzuki and Yanagawa (2013).

References

Airapetyants A.E., Fokin I.M., 2003. Biology of European flying squirrel *Pteromys volans* L. (Rodentia: Pteromyidae) in the North-West of Russia. Russ. J. Theriol. 2: 105–113.

Asari Y., Yanagawa H., 2007. Daily nest site use by the Siberian flying squirrel *Pteromys volans orii* in fragmented small woods. Wildl. Conserv. Jap. 11: 7–10 [in Japanese with English abstract]

Byholm P., Burgas D., Virtanen T., Valkama J., 2012. Competitive exclusion within the predator community influences the distribution of a threatened prey species. Ecology 93: 1802–1808.

Flaherty E.A., Scheibe J.S., Goldigay R., 2008. Locomotor performance in the squirrel glider, *Petaurus norfolcensis*, and the sugar glider, *Petaurus breviceps*. Aust. Mammal. 30: 25–35.

Forstmeier W., Weiss I., 2004. Adaptive plasticity in nest-site selection in response to changing predation risk. Oikos 104: 487–499.

Hanski I.K., Monkkonen M., Reunanen P., Stevens P., 2000a. Ecology of the Eurasian flying squirrel (*Pteromys volans*) in Finland. In: Goldingay R., Scheibe J. (Eds.) Biology of gliding mammals. Filander Verlag, Fürth. 67–86.

Hanski I.K., Stevens P.C., Ihalempia P., Selonen V., 2000b. Home range size, movements, and nest site use in the Siberian flying squirrel. J. Mammal. 81: 798–809.

Hokkanen H., Tormala T., Vuorinen H., 1982. Decline of flying squirrel *Pteromys volans* L. populations in Finland. Biol. Conserv. 23: 273–284.

Holloway G.L., Malcolm J.R., 2007. Nest-tree use by northern and southern flying squirrels in central Ontario. J. Mammal. 88: 226–233.

Jackson S., 2012. Gliding mammals of the world. Csiro publishing, Collingwood.

Kadoya N., Iguchi K., Matsui M., Okahira T., Kato A., Oshida T., Hayashi Y., 2010. A preliminary survey on nest cavity use by Siberian flying squirrels, *Pteromys volans orii*, in forests of Hokkaido Island, Japan. Russ. J. Theriol. 9: 27–32.

Kosinski, Z., Bilinska, E., Derezinski, J., Kempa M., 2011. Nest-sites used by Stock Doves *Columba oenas*: what determines their occupancy? Acta Ornithol. 46: 155–163.

Lampila S., Wistbacka A., Makela A., Orell M., 2009. Survival and population growth rate of the threatened Siberian flying squirrel (*Pteromys volans*) in a fragmented forest landscape. Ecoscience 16: 66–74.

Li P., Martin T.E., 1991. Nest-site selection and nesting success of cavity-nesting birds in high elevation forest drainages. Auk 108: 405–418.

Lindenmayer D., 2002. Gliders of Australia: A Natural History. University of New South Wales Press, New South Wales.

Martin T.E., 1998. Are microhabitat preferences of coexisting species under selection and adaptive? Ecology 79: 656–670.

Mitrus C., Socko B., 2008. Breeding success and nest-site characteristics of red-breasted flycatchers *Ficedula parva* in a primeval forest. Bird Study 55: 203–208.

Murakami T., 2003. Food habits of the Japanese sable *Martes zibellina brachyura* in eastern Hokkaido, Japan. Mamm. Study 28: 129–134.

Reig S., Ruprecht A.L., 1989. Skull variability of *Martes martes* and *Martes foina* from Poland. Acta Theriol. 34: 595–624.

Rendell W.B., Robertson R.J., 1989. Nest-site characteristics, reproductive success and cavity availability for tree swallows breeding in natural cavities. Condor 91: 875–885.

Ruczynski I., Bogdanowicz W., 2005. Roost cavity selection by *Nyctalus noctula* and *N. leisleri* (Vespertilionidae, Chiroptera) in Bialowieza primeval forest, eastern Poland. J. Mammal. 86: 921–930.

Santangeli A., Hanski I.K., Makela H., 2013. Integrating multi-source forest inventory and animal survey data to assess nationwide distribution and habitat correlates of the Siberian flying squirrel. Biol. Conserv. 157: 31–38.

Scheibe J.S., Smith W.P., Bassham J., Magness D., 2006. Locomotor performance and cost of transport in the northern flying squirrel *Glaucomys sabrinus*. Acta Theriol. 51: 169–178.

Selonen V., Sulkava P., Sulkava R., Sulkava S., Korpimaki E., 2010. Decline of flying and red squirrels in boreal forests revealed by long-term diet analyses of avian predators. Anim. Conserv. 13: 579–585.

Suzuki K., Asari Y., Yanagawa H., 2012. Gliding locomotion of Siberian flying squirrels in low-canopy forests: the role of energy-inefficient short-distance glides. Acta Theriol. 57: 131–135.

Suzuki K., Mori S., Yanagawa H., 2011. Detecting nesting trees of Siberian flying squirrels (*Pteromys volans*) using their feces. Mamm. Study 36: 105–108.

Suzuki K., Yanagawa H., 2012. Different nest site selection of two sympatric arboreal rodent species, Siberian flying squirrel and small Japanese field mouse, in Hokkaido, Japan. Mamm. Study 37: 243–247.

Suzuki K., Yanagawa H., 2013. Efficient placement of nest boxes for Siberian flying squirrels: effects of cavity density and nest box installation height. Wildl. Biol. 19: 217–221.

Taulman J.F., 1999. Selection of nest trees by southern flying squirrels (Sciuridae: *Glaucomys volans*) in Arkansas. J. Zool. Lond. 248: 369–377.

Traill B.J., Lill A., 1997. Use of tree hollows by two sympatric gliding possums, the squirrel glider, *Petaurus norfolcensis* and the sugar glider, *P. breviceps*. Austral. J. Mammal. 20: 79–88.

Uraguchi K., 2009. Carnivora Canidae *Vulpes vulpes* (Linnaeus, 1758). In Ohdachi S.D., Ishibashi Y., Iwasa M. A. Saitoh T. (Eds.) The Wild Mammals of Japan. Shoukadoh, Kyoto. 214–215.

Vonhof M.J., Barclay R.M.R., 1996. Roosting-site selection and roosting ecology of forest-dwelling bats in southern British Columbia. Can. J. Zool. 74: 1797–1805.

Wesolowski T., 2002 Anti-predator adaptations in nesting Marsh Tits *Parus palustris*: the role of nest-site security. Ibis 144: 593–601.

Won C., Smith K.G., 1999. History and current status of mammals of the Korean Peninsula. Mammal Rev. 29: 3–33.

Yamaguchi Y., Yanagawa H., 1995. Field observations on circadian activities of the flying squirrel, *Pteromys volans orii*. Mammal. Sci. 34: 139–149 [in Japanese with English abstract].

Associate Editor: L.A. Wauters