Efficient placement of nest boxes for Siberian flying squirrels Pteromys volans: effects of cavity density and nest box installation height

Authors: Suzuki, Kei, and Yanagawa, Hisashi

Source: Wildlife Biology, 19(2) : 217-221

Published By: Nordic Board for Wildlife Research

URL: https://doi.org/10.2981/12-048

Wildl. Biol. 19: 217-221 (2013)
DOI: 10.2981/12-048

Short communication

Efficient placement of nest boxes for Siberian flying squirrels *Pteromys volans*: effects of cavity density and nest box installation height

Kei Suzuki & Hisashi Yanagawa

To improve the effectiveness of research into the Siberian flying squirrel *Pteromys volans*, we investigated the optimal placement of nest boxes. Of the 96 boxes which we installed under various conditions at 10 sites, 47 were occupied by Siberian flying squirrels between spring and autumn. Nest-box height was positively correlated with box occupation; 90% of boxes installed at 2-2.8 m height were used. Cavity density was negatively correlated with occupation, with boxes more frequently used in forests with $<$ 2 cavities/ha. Research in Siberian flying squirrels can thus be made more efficient if nest boxes are installed at a height of 2-2.8 m in forests with $<$ 2 cavities/ha, and by doing observations between spring and autumn.

Key words: Hokkaido, Japan, nest box selection, Pteromys volans, research efficiency, Siberian flying squirrel

Kei Suzuki & Hisashi Yanagawa, The United Graduate School of Agricultural Sciences, Iwate University, Morioka 020-8550, Japan, and Laboratory of Wildlife Ecology, Obihiro University of Agriculture and Veterinary Medicine, Obihiro 080-8555, Japan - e-mail addresses: pteromys@mail.goo.ne.jp (Kei Suzuki); yanagawa@obihiro.ac.jp (Hisashi Yanagawa)

Corresponding author: Kei Suzuki

Received 10 May 2012, accepted 23 November 2012

Associate Editor: Luc A. Wauters

Gliding mammals are important dispersers of ectomycorrhizal fungi (Pyare & Longland 2001) and prey of threatened owl species (Carey et al. 1992, Carey & Peeter 1995, Smith 2007). To evaluate these roles of gliding mammals, it is important to study their locomotor performance and population dynamics, which requires trapping. One useful method of capturing gliding mammals is the use of nest boxes (Selonen & Hanski 2004, Taulman & Smith 2004, Lampila et al. 2009); however, nest boxes tend to have low occupancy rates (Suzuki et al. 2008, Reynolds et al. 2009). We investigated how to solve this problem for the Siberian flying squirrel *Pteromys volans*, a species which can mainly be trapped using nest boxes (e.g. Selonen & Hanski 2004, Selonen et al. 2007).

With the aim of optimising nest box placement in Siberian flying squirrel research, we investigated nest box selection by this species; specifically, we examined the characteristics of the trees in which boxes were installed, the box height and the cavity and box density. We tested the following three hypotheses: 1) nest box use depends on the characteristics of the tree in which the nest box is installed because they affect the flying squirrel species' decision on whether or not to use a particular cavity (Meyer et al. 2005, Holloway & Malcolm 2007); 2) the squirrels favour nest boxes installed at high locations because they usually live in the upper layers of trees and land on tree trunks $\geq$ 1 m above the ground (Suzuki et al 2012); and 3) nest boxes are rarely used if they are installed at high density or in forests with a high cavity density because Siberian flying squirrels, in particular females, tend to reduce home-range overlap (Asari 2008).

Methods

Study areas

We surveyed forests (42°51'-53'N, 143°09'-11'E) in Obihiro (in Hokkaido), northern Japan, occupied by

Table 1. Parameters of forests and woods in which nest boxes were installed. CD: cavity density; NBD: nest box density; FS: forest size; NBH: nest box height; TH: tree height (mean ± SD); DBH diameter at breast height (mean ± SD); CH: canopy height (mean ± SD); CP: percentage of conifer; LP: percentage of live tree.

					Nest box installation tree				
Forest type	CD (number/ha)	NBD (number/ha)	FS (ha)	NBH (m)	TH (m)	DBH (cm)	CH (m)	CP (%)	LP (%)
Riparian forest	0.9	5.2	4.5	1.7 ± 0.4	13.5 ± 3.5	21.9 ± 8.1	7.6 ± 2.9	0	100
Riparian forest	0.5	1.9	4.1	1.7 ± 0.7	14.2 ± 4.5	20.7 ± 7.8	10.5 ± 4.3	0	100
Riparian forest	1.7	2.0	3.0	1.5 ± 0.3	16.2 ± 4.9	27.2 ± 9.2	8.3 ± 4.7	0	83
Riparian forest	3.2	5.0	2.2	1.5 ± 0.5	14.6 ± 3.3	22.9 ± 7.4	10.0 ± 2.8	0	100
Riparian forest	0.6	6.0	1.7	1.6 ± 0.3	12.5 ± 1.6	17.3 ± 6.1	9.2 ± 2.9	0	100
Small forest	1.9	4.8	3.1	1.6 ± 0.6	17.5 ± 8.1	28.7 ± 10.3	9.2 ± 8.0	60	80
Small forest	3.3	6.7	0.6	2.0 ± 0.5	17.7 ± 4.0	26.8 ± 9.8	11.2 ± 2.3	0	100
Small forest	5.0	7.5	0.4	2.0 ± 0.7	18.8 ± 2.7	30.1 ± 4.4	13.8 ± 4.8	33	100
Windbreak woods	2.7	6.0	1.5	1.4 ± 0.5	16.6 ± 4.8	27.8 ± 5.9	9.1 ± 5.8	33	89
Windbreak wood	0.0	7.8	0.9	1.3 ± 0.3	18.5 ± 6.2	34.1 ± 5.8	16.1 ± 5.9	100	100

Siberian flying squirrels. The forests in this area have been fragmented by clearance for agriculture, road-building and urban development. They currently comprise conifers (29%) including Korean pine *Pinus koraiensis*, eastern white pine *Pinus strobus* and Japanese larch *Larix leptolepis* and broad-leaved trees (71%) including Japanese white birch *Betula platyphylla*, Manchurian walnut *Juglans mandshurica* and Japanese emperor oak *Quercus dentata*. In the forests, height and diameter at breast height (DBH) of trees (N = 173) averaged 15.3 ± 5.6 (SD) m and 26.0 ± 11.3 cm, respectively, and tree density averaged 692/ha (Suzuki et al. 2012, Suzuki & Yanagawa 2012).

Nest box survey

We installed 96 boxes (volume 3,456 cm^3, measuring 24 cm vertical depth × 8 cm range × 18 cm horizontal depth, with a 4.5-cm circular entrance near the top of one side wall and a 2.5-cm wall thickness) in June 2010 under various conditions at 10 sites (Table 1). In 2010, we checked the boxes in July, September, October and November, and in 2011 we checked them in January, May, June, July, August and October. To clarify nest-box use in winter, we removed nest materials after the October 2010 check, and did not remove them after any other checks. All nest materials present from November 2010 onwards were therefore counted as new nest materials. We marked captured Siberian flying squirrels with individually numbered ear tags (KN-295-A, Natsume Seisakusho Co., Ltd) and calculated the smallest number of individual squirrels using each nest box. We categorised the nest boxes as 'used' if they contained Siberian flying squirrels or their nest materials, or both. In contrast, we categorised the boxes as 'unused' if squirrels or materials were not observed in the box throughout the study period.

To examine nest-box selection by Siberian flying squirrels, we recorded cavity densities in the study areas (see Table 1). We have been surveying tree cavities in this area since 2003 (Muraki & Yanagawa 2006, Nakama & Yanagawa 2009, Suzuki et al. 2011b, Suzuki & Yanagawa 2012), and for this study we again surveyed the cavities in all the trees in the area. We were able to check all of the trees because the area of forest in this location is very small (Konno 2002). We calculated the cavity density from the results of these surveys. In addition, we examined five parameters of the trees in which the nest boxes were installed, i.e. tree type (broad-leaved 79%, conifer 21%), tree health (dead 5%, alive 95%), tree height, diameter at breast height (DBH) and canopy height (Table 2). We did this because we considered these attributes to likely be influencing nest site selection by gliding mammals. Canopy height was set to 0 for dead trees. Tree height, DBH and canopy height were summarised as principal components to give a single indicator of tree size because generally these variables are highly positively correlated. We also recorded nest-box entrance heights (see Table 2).

Table 2. Parameters of trees in which nest boxes were installed, and nest box installation heights. Canopy height was set to 0 for dead trees.

Variable	Mean	SD	Minimum	Maximum
Tree height (m)	15.4	5.1	3.2	27.0
Diameter at breast height (cm)	24.7	8.9	4.8	44.6
Canopy height (m)	9.7	5.1	0.0	23.0
Nest box height (m)	1.6	0.5	0.7	2.8

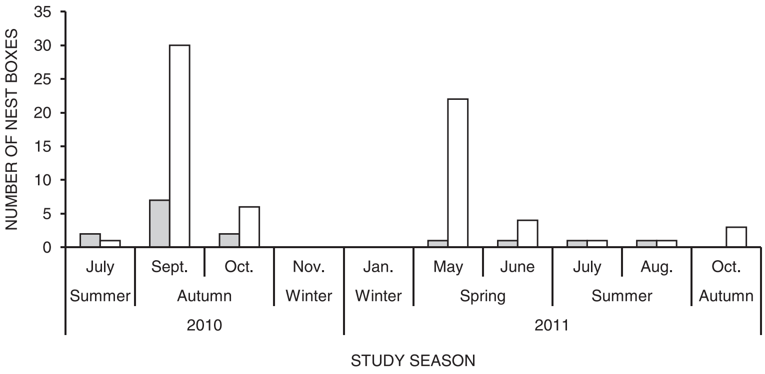

Figure 1. Number of nest boxes used by Siberian flying squirrels changes seasonally. Grey bars show the number of nest boxes in which squirrels were found. White bars show the number of boxes in which new nest materials were found.

Data analysis

To clarify nest-box selection by Siberian flying squirrels, we used a generalised linear mixed model (GLMM) to examine the influence of these attributes on nest-box use by squirrels. The parsimony of the models was assessed by using Akaike's Information Criterion (AIC). In the GLMM, we treated nest box occupancy status ('used' vs 'unused') as the dependent variable. As fixed effects we used tree type, tree health, a first principal component (PC1, proportion of variance = 78.8) consisting of tree height (factor loading = 0.60), DBH (0.57) and canopy height (0.56), nest-box height, cavity density and nest-box density (see Table 1). In addition, to avoid any influences of differences in the number of nest boxes installed and the occurrence of squirrels with differences in forest size, we used the number of boxes and forest size as fixed effects. Site identity (10 sites) was treated as a random effect.

Results

Nest-box use

During our study period, a total of 47 nest boxes (49%) were used (i.e. squirrels or nest materials, or both, were present) by at least 15 different Siberian flying squirrels and 49 boxes were unused. Squirrels or their new nest materials, or both, were observed only in July-October 2010 and May-October 2011; they were absent in November 2010 and January 2011 (Fig. 1).

Nest-box selection

As a result of model selection, two variables (i.e. nest-box height and cavity density) were ranked in the top model (Table 3). This top model had the lowest number of variables. These two variables were also included in the second and third models, which had a ΔAIC of < 2. Accordingly, model selection based on GLMM highlighted these variables as important factors affecting nest-box selection by Siberian flying squirrels (Table 4).

Nest-box height was positively correlated with use by the squirrels. The height of the nest boxes selected averaged 1.8 m (SE = 0.06), whereas the mean height of unused boxes was 1.3 m (SE = 0.06). Notably, 90% (18/20) of nest boxes installed at heights of at least 2 m were used, but none below 1 m were used (Fig. 2). Cavity density was negatively correlated with nest-box use (Fig. 3). The rate of nest-box use increased in forests with < 2 cavities/ha. These results indicate that Siberian flying squirrels tend to select nest boxes installed in higher positions or in forests with a lower cavity density.

Table 3. Model selection using a generalised linear mixed model. PC1 is a principal component summarising tree height, diameter at breast height and canopy height; ΔAIC shows the difference in AIC between the top-ranked model and the model.

Model structure	AIC	ΔAIC	Deviance explained (%)
Nest box height + Cavity density	101.7	0.0	29.5
Nest box height + Cavity density + PCI	101.8	0.1	31.0
Nest box height + Cavity density + PCI + Forest size	103.6	1.9	31.1
Nest box height + Cavity density + PCI + No. of nest box	103.7	2.0	31.1
Nest box height + Cavity density + Forest size + No. Of nest box	103.7	2.0	30.3
Null	137.0	35.3	

Table 4. Result of generalised linear mixed model in the two top models.

Variable	Coefficient	SE	χ^2	P-value
1st model				
Nest box height	3.57	0.80	35.02	< 0.001
Cavity density	-0.80	0.24	9.19	0.002
2nd model				
Nest box height	3.59	0.82	34.34	< 0.001
Cavity density	-0.71	0.24	9.75	0.002
PCI	0.36	0.27	1.96	0.162

Discussion

Two characteristics of the squirrels' use of nest boxes were revealed. First, the nest boxes were used from spring to autumn only (May-October) and not during winter (November-January). Second, Siberian flying squirrels preferred to use nest boxes installed at heights of 2.0-2.8 m (see Fig. 2) or in forests with < 2 cavities/ha (see Fig. 3).

Nest boxes are useful for capturing flying squirrel species (Selonen & Hanski 2004, Taulman & Smith 2004, Lampila et al. 2009). However, there has hitherto been no research into the efficient placement of nest boxes for flying squirrels, despite their low nesting ratios (Suzuki et al. 2008, Reynolds et al. 2009). The installation method that we propose may help resolve this problem because it results in high nesting rates of Siberian flying squirrels.

Siberian flying squirrels did not use the boxes during winter. Nest box uses by the squirrels are known to be low during winter in Japan (Yanagawa 1994, Asari & Yanagawa 2008); we believe that this is due to the boxes' poor heat retention (Yanagawa 1994). During winter, the squirrels move into deeper tree cavities (average depth of 20.2 cm) to escape the cold by means of group nesting (Nakama & Yanagawa 2009). Our nest boxes were not used during winter despite their large vertical depth (24 cm), making them sufficient for group nesting. Nest-box surveys should therefore not be done during winter because of their inefficiency, or nest boxes should be designed to better support flying squirrel use in cold weather.

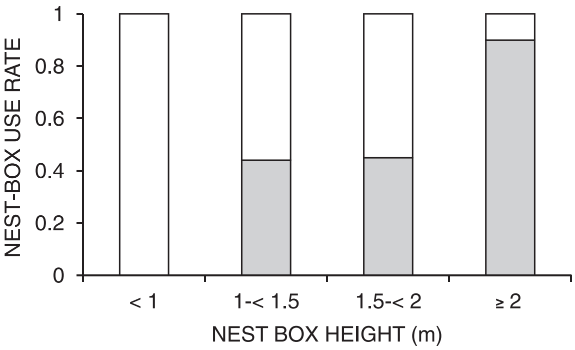

Figure 2. Relationship between nest box height and nest box use by Siberian flying squirrels. Grey bars show the fraction of nest boxes used; white bars, the fraction of boxes unused. There were 11 nest boxes in the < 1 m height class, 25 in the 1-1.5 m class, 40 in the 1.5-2 m class and 20 in the 2-2.8 m class.

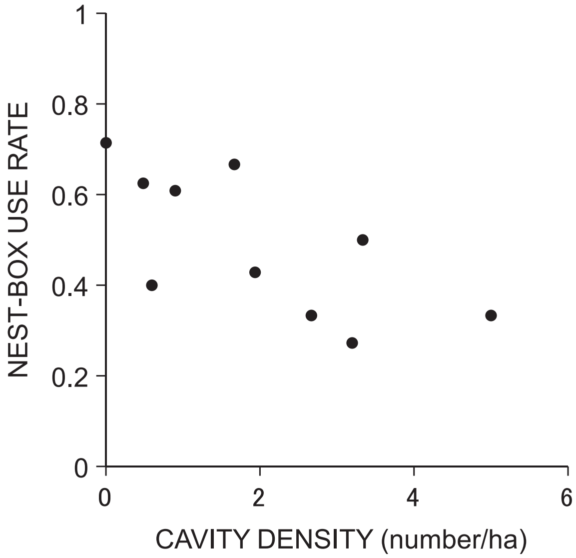

Figure 3. Variation in rates of nest-box use by Siberian flying squirrels according to cavity density in 10 forests.

Siberian flying squirrels use nest boxes in forests with lower cavity densities (see Fig. 3); however, this species may not be common in forests with low cavity densities (Selonen & Hanski 2012). It should therefore be confirmed beforehand whether it is present in any given environment. This can easily be done by searching under cavity trees for the squirrels' accumulated faeces (Suzuki et al. 2011b).

Previously, nest boxes for Siberian flying squirrels were frequently installed at heights of > 3 m (Yanagawa 1994, Masuda 2003, Suzuki et al. 2011a). However, observing nest boxes in high positions requires increased effort and thus reduces research efficiency, e.g. the cost of observing a box installed at > 2.5 m height is triple the cost at 1.5-2.0 m (Ando 2007). According to our results and those of Ando (2007), to increase research efficiency, nest boxes should not be installed at heights > 3 m.

These results indicate that research on Siberian flying squirrels can be made more efficient if 1) nest boxes are installed at 2-2.5 m height, 2) if they are installed in forests with $<$ 2 cavities/ha, and 3) by observing the boxes between spring and autumn only.

Acknowledgements - we thank Drs. M. Ando, T. Oshida, M. Takada and Y. Asari for their constructive comments on this manuscript. We also thank M. Minoshima for support with the field work.

References

Ando, M. 2007: Educational use of the nest box for observation of arboreal small mammals. - Environmental Education 16: 24-32. (In Japanese).

Asari, Y. 2008: Biology and conservation of the Siberian flying squirrel in small woods. - PhD thesis, Iwate University, Japan, 89 pp. (In Japanese with an English summary; title translated from Japanese into English).

Asari, Y. & Yanagawa, H. 2008: Daily nest site use by the Siberian flying squirrel *Pteromys volans orii* in fragmented small woods. - Wildlife Conservation Japan 11: 7-10. (In Japanese with an English summary; title translated from Japanese into English).

Carey, A.B., Horton, S.P. & Biswell, B.L. 1992: Northern spotted owls: influence of prey base and landscape character. - Ecological Monographs 62: 223-250.

Carey, A.B. & Peeter, K.C. 1995: Spotted owls: resource and space use in mosaic landscapes. - Journal of Raptor Research 29: 223-239.

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

Konno, Y. 2002: Present status of remnant forest in Obihiro, eastern Hokkaido, Japan. - Obihiro Asia and the Pacific Seminar on Education for Rural Development (OA-SERD), pp. 39-46.

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.

Masuda, Y. 2003: Daily activity of the flying squirrel (*Pteromys volans orii*). - Bulletin of the Shiretoko Museum 24: 53-58. (In Japanese).

Meyer, M.D., Kelt, D.A. & North, M.P. 2005: Nest trees of northern flying squirrels in the Sierra Nevada. - Journal of Mammalogy 82: 275-280.

Muraki, N. & Yanagawa, H. 2006: Seasonal change in the utilization of tree cavities by wildlife in Obihiro City. - Tree and Forest Health 10: 69-71. (In Japanese with an English summary; title translated from Japanese into English).

Nakama, S. & Yanagawa, H. 2009: Characteristics of tree cavities used by *Pteromys volans orii* in winter. - Mammal Study 34: 161-164.

Pyare, S. & Longland, W.S. 2001: Patterns of ectomycorrhizal-fungi consumption by small mammals in remnant old-growth forests of the Sierra Nevada. - Journal of Mammalogy 82: 681-689.

Reynolds, R.J., Fies, M.I. & Pagels, J.F. 2009: Communal nesting and reproduction of the southern flying squirrel in Montane Virginia. - Northeastern Naturalist 16: 563-576.

Selonen, V. & Hanski, I.K. 2004: Young flying squirrels (*Pteromys volans*) dispersing in fragmented forests. - Behavioral Ecology 15: 564-571.

Selonen, V. & Hanski, I.K. 2012: Dispersing Siberian flying squirrels (*Pteromys volans*) locate preferred habitats in fragmented landscapes. - Canadian Journal of Zoology 90: 885-892.

Selonen, V., Hanski, I.K. & Desrochers, A. 2007: Natal habitat-biased dispersal in the Siberian flying squirrel. - Proceedings of the Royal Society B 274: 2063-2068.

Smith, W.P. 2007: Ecology of *Glaucomys sabrinus*: habitat, demography, and community relations. - Journal of Mammalogy 88: 862-881.

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 Theriologica 57: 131-135.

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

Suzuki, K., Ogawa, H., Amano, T. & Ando, M. 2008: Habitat preference and nest box use of the small Japanese flying squirrel *Pteromys momonga* in the Tanzawa Mountains. - Journal of Agriculture Science, Tokyo University of Agriculture 53: 13-18. (In Japanese with an English summary; title translated from Japanese into English).

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. - Mammal Study 37: 243-247.

Suzuki, M., Kato, A., Matsui, M., Okahira, T., Iguchi, K., Hayashi, H. & Oshida, T. 2011a: Preliminary estimation of population density of the Siberian flying squirrel (*Pteromys volans orii*) in natural forest of Hokkaido, Japan. - Mammal Study 36: 155-158.

Taulman, J.F. & Smith, K.G. 2004: Home range and habitat selection of southern flying squirrels in fragmented forests. - Mammalian Biology 69: 11-27.

Yanagawa, H. 1994: Field study of *Pteromys volans orii* using bird-box. - Forest Protection 231: 20-22. (In Japanese).