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Why do small Japanese flying squirrels, *Pteromys momonga*, prefer to use bark of Japanese cedar as a nest material ?

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The small Japanese flying squirrels, *Pteromys momonga*, is known to prefer the barks of Japanese cedar, *Crytomeria japonica*, as a nest material in their natural habitats. In the present study, two experiments were performed to examine the following hypothese: (1) the squirrels prefer cedar bark as a materials because it is easier to strip than the barks of other tree species; and (2) Nests made of cedar bark have better resistance to penetration of water into the core, where the squirrels rest, as compared with nests made of the barks of other tree species. The results denied the hypothesis (1) and supported the hypothesis (2).

Keywords
small Japanese flying squirrels, nest material, bark of Japanese cedar, water penetration

1 Introduction

The small Japanese flying squirrel, *Pteromys momonga*, is a species peculiar to Japan and is listed as an endangered species in the Red Data Book of many prefectures [1]. However, there is little information on their natural history, including their life cycle, partly because of difficulty of conducting research on this small, nocturnal, flying mammals[1].

Previous studies on the habitat and nesting of the small Japanese flying squirrels indicate that they tend to make nests in cavities of Japanese cedar, *Crytomeria japonica*, and use the bark of this tree as a nest material[2,3,4]. Kobayashi[4] reported that small Japanese flying squirrels made their nests exclusively using Japanese cedar bark in all of the 20 nest boxes that were put up in an area of approximately 10 ha, where there were only a few cedar trees and a large number of other trees. This observation indicates that the squirrels used the bark of Japanese cedars trees far, at least 100m away, from their nests. These facts suggest that Japanese cedar bark may be important for survival and reproduction of the small Japanese flying squirrels.

In the present study, two experiments were performed to examine the following two hypotheses on the preference of small Japanese flying squirrels for the bark of Japanese cedar as a nest material : (1) the bark of Japanese cedar trees is easier to strip than the barks of other trees ; and (2) nests made of Japanese cedar bark have better resistance to penetration of water into the core, where the squirrels rest, as compared with nests made of the bark of other trees.

The hypothesis (2) was proposed on the basis of the reports by Sakaguchi[2] and Kobayashi[4]. Sakaguchi[2] found that in the natural habitat of small Japanese flying squirrels, these squirrels built a frame with branches and leaves of Japanese

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cedar by bending them and made a nest of cederbark inside this frame. Such nests are subjected to weathering by rain water. It is therefore possible that the nests made of Japanese cedar are able to resist penetration of water. Kobayashi[4] reported that even when the surface of Japanese cedar in the nest box was wet with rain water, the core of the nest was wet little.

2 Experiment I

Experiment I was performed to investigate the hypothesis (1) by offering squirrels barks artificially stripped from the trunks of three species of trees including the Japanese cedars. If the hypothesis (1) is correct, the squirrels may not show preference for the cedar bark over the barks of the other trees since all barks were offered after stripped from their tree trunks.

2.1 Methods

In June of 2011, five small Japanese squirrels (weight and sex; 136 g ♀, 122 g ♂, 116 g ♂, 78 g ♀, and 74 g ♂) were removed from the nest boxes set up on trees in the forest of Chizu, Tottori prefecture, which is composed of planted cedar trees and natural laurel and deciduous trees. The squirrels were captured under the official permission of capture and keeping. One box contained two squirrels of 78 g (♀) and 74 g (♂); presumably, they were subadult and had never left the nest.

Figure 1 A : stem of tree from which bark was stripped. B : barks of cedar, cypress and chestnut placed in round transparent cases. C : experimental cage (left) connected to cage where a test squirrel is reared via a corridor.

The squirrels were reared separately in cages measuring 45 × 40 × 45 cm placed in a laboratory for 1 to 2 weeks before the experiment. They were nocturnal; that is, they rested in the nest boxes (18 × 18 × 23 cm) placed in the cages in the daytime and spent nights outside the nest boxes. They were fed leaves of oaks (*Quercus serrata*, *Q. acutissima*, and *Q. myrsinaefolia*) and *Castanopsis cuspidata* and dried vegetables (carrots, cabbage, and soybeans). They had free access to food and drink.

The experiment was performed in the laboratory where the squirrels were kept. The temperature of the laboratory was maintained at 15°C ; it was light (920 lux) between 07:00 and 19:00 and dark (7 lux) between 19:00 and 07:00. The procedure was as follows. Barks of cedar, cypress (*Chamaecyparis obtusa*), and chestnut (*Castanea crenata*) were used for the experiment because these tree species were common in the natural habitat of the squirrels. The barks of these species were stripped, mostly by hand and occasionally with a knife, and cut into pieces of approximately 2 × 20 cm (2 to 4 mm thick). Then, 15 pieces of each type of bark were placed in around transparent cases (14 cm across, 5.5 cm high) and kept on the floor of the experimental cage. The total weight of the 15 pieces of each tree bark was 58 to 68 g.

The experimental cage was connected to the cages where the squirrels were reared via a corridor measuring 10 × 10 × 28 cm. The squirrels were free to move between the cages and made nests in the nest boxes with barks brought from the round cases (Fig.1).

The barks were left in the cases for 4 days, during which the remaining barks of each tree species left in the cases every day waswere weighed every day. The weights of barks that the squirrels carried into the nest boxes were calculated by subtracting the remaining weight from the weight at the start of the day.

Table 1 Weights of barks carried by squirrels into the nest box as nest material for 4 days

	Squirrel				
Bark from	136g ♀	122g ♂	116g ♂	78g ♀	74g ♂
Ceder	39.8g	46.3g	44.2g	36.8g	32.2g
Cypress	7.2g	7.4g	8.1g	6.5g	8.2g
Chestnut	5.9g	6.6g	5.7g	3.6g	2.8g

2.2 Results and Discussion

All three adult squirrels carried the bark of Japanese cedar much more than cypress and chestnut barks (Table 1). The two young squirrels (78 g ♀ and 74 g ♂), which were believed from a litter to have never had left the nest and therefore have no experience of making a nests, also carried cedar bark much more than the other barks.

These results indicate that the reason the squirrels prefer cedar bark is not because it is easier to strip from the tree compared with the barks of other trees. These results suggest that choosing cedar bark is not something to learn from many trials.

3 Experiment II

Experiment II was carried out in July of 2011. The experiment was designed to investigate the hypothesis (2).

Nests made of cedar bark only and nests made of cypress bark only were exposed to natural rain, and the degree of wetness of the core of each nest was examined. If the hypothesis (2) is correct, the degree of wetness of the core may be lower in the cedar nests than in the cypress nests.

3.1 Method

Experiment II was performed a few weeks after experiment I using the same five squirrels as in experiment I. Cypress bark was used for comparison to ceder bark in the experiment for the following reason. Cedar and cypress are species close to each other and their barks resemble in appearance although the squirrels prefer cedar much more to cypress.

Nests made of cedar bark only and one nest made of cypress bark only were prepared by the squirrels when they were offered only cedar bark or only cypress bark in the same experimental set-up as described for experiment I. Each squirrel made one cedar bark nest and one cypress bark nest ; then, a total of five cedar bark nests and five cypress bark nests were prepared. The weights of the cedar bark nests were 42.3 g, 38.5 g, 35.6 g, 28.9 g, and 28.2 g, and the weights of the cypress bark nests were 34.6 g, 30.5 g, 28.8 g, 28.1 g, and 23.9 g. The nests were stored in a refrigerator at −10°C.

Receiving a forecast of rain, the ten nests were placed in the forks of branches of trees on the campus of Tottori University of Environmental Studies and exposed directly to rains for 2 days (48 h) in July of 2011. The precipitation of the two consecutive rainy days was 21.5 mm/day and 61 mm/day, respectively.

Then, each nest was brought in the laboratory and divided into the core part and surface part. The weight ratio between the core and surface parts was approximately 1:5. Approximately 17% (1/6) of nest materials was probably used to lap around the squirrel to a few centimeters thickness in the nest. Then, all nest parts were placed in a hot-air

Table 2 Degree of wetness of surface part and core part of nests made of barks of ceder and cypress

A. Nest made of ceder bark

Squirrel	Degree of wetness of surface part (%)	Degree of wetness of core part (%)	Core/Surface
136g ♀	66.2	37.7	0.57
122g ♂	66.9	36.4	0.55
116g ♂	69.8	35.6	0.51
78g ♀	71.1	38.6	0.54
74g ♂	74.3	39.5	0.53

B. Nest made of cypress bark

Squirrel	Degree of wetness of surface part (%)	Degree of wetness of core part (%)	Core/Surface
136g ♀	65.2	51.6	0.79
122g ♂	68.4	45.8	0.67
116g ♂	58.6	43.9	0.75
78g ♀	74.1	57.3	0.77
74g ♂	72.7	48.9	0.66

See text for definition of "Degree of wetness". Core/Surface means "Degree of wetness of surface part"/"Degree of wetness of surface part". Core/Surface of ceder bark is significantly smaller than of cypress bark ($p < 0.01$ t-test).

rapid-drying oven at 80°C for 3 h.

The degree of wetness of each part was determined as follows: the amounts of water absorbed in the core and surface parts were calculated by comparing the weights of each part before and after drying. The degree of wetness was calculated as follows : weight of water absorbed in each nest part/ weight of each part before drying × 100%

3.2 Results and Discussion

Of the five cedar bark nests, the degrees of wetness of the surface and core parts were 66.2% (52.1g before drying ; 17.6g after drying) and 37.7% (11.9g; 7.4g); 66.9% (48.8g; 15.9g) and 36.4% (9.6g; 6.1g); 69.8% (45.5g; 13.7g) and 35.6% (8.1g; 5.2g); 71.1% (35.3b; 10.2g) and 38.6% (8.2g; 5.4g) ; and 74.3% (36.1g; 9.3g) and 39.5% (7.8g; 4.7g), respectively (Table 2). On the other hand, of the five cypress bark nests, the degrees were 62.6% (47.3g; 17.7g) and 43.9% (9.2g; 5.2g); 65.2% (39.6g; 13.8g) and 51.6% (8.3g; 4.0g); 68.4% (34.0g; 10.7g) and 45.8% (7.8g; 4.2g); 72.7% (36.5g; 10.0g) and 48.9% (7.7g; 3.9g); and 74.1% (32.4g; 8.4g) and 57.3% (6.3g; 2.7g).

These results indicate that the cedar bark nests tended to resist penetration of water into their core to a greater degree compared with the cypress bark nests ($p < 0.01$, Student's t-test).

The cedar bark nests and cypress bark nests made by the squirrels and then used in the experiment differed slightly in weight; the cedar bark nests were slightly heavier than the cypress bark nests. However, the difference in weight was not believed to account for lesser water absorption by the core of cedar bark nests than by that of the cypress bark nests. Neither the comparison among cedar bark nests of different weights nor the comparison among cedar bark nests of different weights showed that heavy nests were more resistant to water penetration into the nest core. It is therefore suggested that the difference in water penetration resistance between cedar bark and cypress bark nests results from some physical difference between the barks of the two species.

The appearance of cedar bark and cypress bark suggests the following explanation for the greater resistance of cedar bark nests to water penetration into the core. Fibers that the squirrels can obtain from cedar bark by ripping it are finer and longer than those from cypress bark, and nests constructed with cedar bark fibers may have more chinks with greater resistance against water penetration than nests constructed with cypress bark fibers.

It is not clea from the present study wheather the squirrels prefer the cedar bark innately or by learning as infants. If the cedar bark fiber is significantly important as a nest material for survival and reproduction of small Japanese flying squirrels, the existence of cedar trees will be essential for the conservation of their natural habitat.

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ニホンモモンガ *Pteromys momonga* はなぜ巣材としてスギの樹皮を好むのか

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ニホンモモンガ *Pteromys momonga* は，自然生息地において，巣材としてスギ *Crytomeria japonica* の樹皮を好んで用いることが知られている．本研究では，巣材へのスギの樹皮の選択的利用の理由に関する以下の (1)，(2) の仮説を検証するため，2つの実験が行われた．(1) スギの樹皮を巣材として好むのは，それが，他の樹種の樹皮と比べて，幹から剥ぎ取りやすいためである．(2) スギの樹皮でつくられた巣は，他の樹種の樹皮でつくられた巣に比べ，水が中心部へ浸透するのを防ぐことにより優れている．実験の結果は，(1) の仮説を否定し，(2) の仮説を支持するものであった．

キーワード ニホンモモンガ，巣材，スギの樹皮，水の浸透

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