Zoogeography of Terrestrial Mammals on Kunashiri Island: Are There Arboreal Small Mammals on this Small Boreal Island?

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ABSTRACT

On Kunashiri Island which is adjacent to the Shiretoko Peninsula of Hokkaido Island, we searched for three arboreal small mammal species common on Hokkaido Island: Siberian flying squirrel (Pteromys volans), small Japanese field mouse (Apodemus argenteus), and Eurasian red squirrel (Sciurus vulgaris). To find Siberian flying squirrel and small Japanese field mouse, we set 30 wooden nest boxes in a natural boreal mixed forest in the southern part of Kunashiri Island for two years (July 2013-August 2015). We did not find either species. In July 2012, we interviewed 30 inhabitants of Kunashiri Island about Eurasian red squirrel. No inhabitants saw Eurasian red squirrels. Therefore, it was suggested that there are no arboreal small mammals on Kunashiri Island, as reported previously. Loss of these three species could be due to severe forest reduction and environmental change during Pleistocene glaciation.

Key words: Apodemus argenteus, nest box, Pleistocene, Pteromys volans, Sciurus vulgaris

INTRODUCTION

In the Pleistocene, forest vegetation during glacial periods was quite different from during interglacial periods in the Northern Hemisphere [e.g. 1]. These forest dynamics indicate that during glaciation, forest mammals shifted distributions from north to south in North America [2] and Eurasia [3]. After glaciation, continental forest mammals expanded with forest from glacial refugia into northern parts ([2, 3]).

During the glaciations, many small boreal islands were connected with the continent due to lower sea level [e.g. 4]. Despite the connection, refugia for forest mammals would be limited on these islands during glaciations. After glaciation, forest mammals may not have been able to expand from continental refugia back to islands, because of geographic isolation by the sea.

Hokkaido, whose area encompasses an area of 78,073km², is the northernmost island of four Japan’s main islands. This island is mainly covered with boreal coniferous forests characterized by Picea and Abies, with Tsuga present in some montane forests at high elevations [5-7]. During the last glaciation, montane forests characterized by Pinus and Larix dominated in northern Hokkaido, with boreal coniferous forests shifting to southern Hokkaido [8-10]. These forest dynamics during the Pleistocene affected phylogeography of forest mammals. As a result, there were not many forest mammals in northern Hokkaido. They retreated to refugia in the southern parts of Hokkaido. In fact, the Hokkaido population of Eurasian red squirrels (Sciurus vulgaris orientis)
shows signs of expansion after restriction to southern glacial refugia [11].

To support this biogeographic scenario for forest mammals in Hokkaido, we looked for a small island meeting the following two requirements: 1) the island was connected with Hokkaido during glacial periods, and isolated from Hokkaido after glaciation; and 2) the island contained no refuge area for many forest mammals, forming montane and tundra vegetations. Although the island might retain a few forest mammals during the glacial period, many forest mammal species were not present compared to the mammal fauna on Hokkaido Island. Therefore, we expect that mammal fauna, which would be similar to that of non-refuge areas during glacial periods on Hokkaido Island, is presently observed on the island.

To test this biogeographic conjecture, Kunashiri Island, which is adjacent to the Shiretoko Peninsula of Hokkaido, could be suitable (Fig. 1). This island is located just north of Hokkaido. It is about 30 km distant from Hokkaido and has an area of 1,489 km². The contribution of the southern biota (from Asian mainland by way of Sakhalin and Hokkaido) to the species diversity of the Kuril was considerably greater than the northern biota (from Asian mainland by way of Kamchatka) [12]. Kunashiri Island is thought to have been connected with Hokkaido Island during the late Pleistocene [13]. Even after the last glaciation (ending 10,000 to 7,000 years ago), some terrestrial mammals may have emigrated from Hokkaido to Kunashiri Island [14]. For the past 7,000 years, Kunashiri Island has been isolated from Hokkaido. Except for pinniped species, there are currently 43 mammal species in Hokkaido [15] and 26 on Kunashiri Island [14, 16] (Table 1). Therefore, 39.5% of Hokkaido species are not found on Kunashiri Island. This includes species well adapted to forest environments: sika deer (Cervus nippon), raccoon dog (Nyctereutes procyonoides), Eurasian red squirrel (Sciurus vulgaris), Siberian flying squirrel (Pteromys volans), and small Japanese field mouse (Apodemus argenteus) [15]. Due to their nocturnal and arboreal habits, it is not easy to observe small forest mammals, such as Siberian flying squirrel and small Japanese field mouse. To test whether the forests were markedly reduced on Kunashiri Island during glaciation, investigation of mammal distributions, especially, of

Fig. 1 Map of Kunashiri Island. Solid circle indicates region where we set 30 wooden nest boxes.
Table 1 Land mammal species occurring on Kunashiri and Hokkaido Islands [14-16].

| Order      | Species                        | Kunashiri Island | Hokkaido Island |
|------------|--------------------------------|-----------------|----------------|
| Insectivora| Sorex minutissimus             | *               | *              |
|            | Sorex caecutiens               | *               | *              |
|            | Sorex unguiculatus             | *               | *              |
|            | Sorex gracilimus               | *               | *              |
| Lagomorpha | Lepus timidus                  | *               | *              |
|            | Ochotona hyperborea            | —               | *              |
| Rodentia   | Tamias sibiricus               | *               | *              |
|            | Sciurus vulgaris               | —               | *              |
|            | Pteromys volans                | —               | *              |
|            | Apodemus speciosus             | *               | *              |
|            | Apodemus argenteus             | —               | *              |
|            | Apodemus peninsularis          | —               | *              |
|            | Rattus norvegicus              | *               | *              |
|            | Myodes rufocanus               | *               | *              |
|            | Myodes rex                     | *               | *              |
|            | Myodes rutilus                 | —               | *              |
|            | Mus musculus                   | *               | *              |
| Carnivora  | Vulpes vulpes                  | *               | *              |
|            | Nyctereutes procyonoides       | —               | *              |
|            | Mustela nivalis                | *               | *              |
|            | Mustela erminea                | *               | *              |
|            | Martes zibellinae               | *              | *              |
|            | Ursus arctos                   | *               | *              |
| Artiodactyla| Cervus nippon                  | —               | *              |
| Chiroptera | Rhinolophus ferrumequinum      | —               | *              |
|            | Rhinolophus cornutus           | —               | *              |
|            | Eptesicus nilssonii            | *               | *              |
|            | Nyctalus aviator               | —               | *              |
|            | Pipistrellus abramus           | —               | *              |
|            | Barbastella darjelingensis     | *               | *              |
|            | Plecotus sacimontis            | *               | *              |
|            | Hypsugo alaschanicus           | —               | *              |
|            | Vespertilio murinus            | —               | *              |
|            | Vespertilio sinesis            | —               | *              |
|            | Myotis frater                  | —               | *              |
|            | Myotis granilis                | *               | *              |
|            | Myotis ibernikovi              | *               | *              |
|            | Myotis macrodactylus           | *               | *              |
|            | Myotis bominibus               | *               | *              |
|            | Myotis petax                   | *               | *              |
|            | Murina hilgendorfi             | *               | *              |
|            | Murina ussurienstis            | *               | *              |
|            | Tadarida insignis              | —               | *              |

Asterisks and hyphens mean presence and absence of species, respectively.

In Hokkaido, there are three arboreal mammals: Eurasian red squirrel, Siberian flying squirrel, and small Japanese field mouse [e.g. 15]. We used wooden nest boxes to investigate the distribution of Siberian flying squirrels and small Japanese field mice on Kunashiri Island. The nest box is a useful tool for investigating arboreal small mammals and is often used in ecological studies of Siberian flying squirrels [17] and small Japanese field mice [18] in Hokkaido. Nest boxes have not been used on Kunashiri Island. We also interviewed people residing on Kunashiri Island for observation of red squirrels. This squirrel is easily observed in Hokkaido. Here, we discuss the biogeography of mammals occurring on Kunashiri Island.

MATERIALS AND METHODS

Field survey for Pteromys volans and Apodemus argentaeus

On 3 August 2013, we surveyed for Siberian flying squirrels and small Japanese field mouse by placing nest boxes in a natural forest in the southern part of Kunashiri Island (44˚01’48” N, 145˚42’56” E) (Fig. 1). The site has an area of about 2.0 ha. It is characterized by natural boreal mixed forest typical of the forest vegetation on Kunashiri Island [e.g. 14, 19]. Dominant stands are Abies sachalinensis and Betula ermanii. Since cavities of Abies sachalinensis are most frequently used by Siberian flying squirrels in Hokkaido [20], we considered this forest suitable for this study. Following Yanagawa [21], 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. Thirty numbered nest boxes were attached to trees at heights of 3 m. We randomly selected the tree species for nest boxes. Nest boxes were placed on 16 Abies sachalinensis, 10 Betula ermanii, 2 Picea jezoensis, 1 Ulmus laciniata, and 1 Fraxinus mandshurica. Following Suzuki et al. [17], we made two line transects with 15 nest boxes on each transect at 20-30-m intervals. Distance between transects was about 30 m. Nest boxes were kept in place for two years. If animals used the boxes, we were usually able to identify species from nest materials in the boxes [e.g. 22]. We checked inside each nest box in the daytime once per year: on 26 July 2014 and 15 August 2015. In the natural forest of Furano, Hokkaido, Siberian flying squirrels used 63% of the nest boxes for six months [17]. The small Japanese field mouse used 0.5% of nest boxes in Shari, Hokkaido, for a year [23]. Therefore, we expected that several nest boxes would be used by those...
species during our study period.

Survey for Sciurus vulgaris

On 5 August 2012, we gave a talk on ecology of squirrels to 30 residents of Kunashiri Island in Furukamappu, the main town on the island. In our talk, we explained the ecological and morphological characteristics of Eurasian red squirrel and showed its many photographs. At that time, we asked our audience if they had seen Eurasian red squirrels on Kunashiri Island.

RESULTS

We did not find individuals of Siberian flying squirrel and small Japanese field mouse or their nest materials in any nest box. On 26 July 2014, we found six nest boxes (20% of total nest boxes) were used by Paridae birds. Five of these nest boxes only had nest materials, making it difficult to identify bird species. One nest box with nest materials had six Poecile varius chicks. On 15 August 2015, ten nest boxes (33% of total nest boxes) were used by Paridae birds. We found nest materials in seven nest boxes and an egg with nest materials in two nest boxes. In one nest box, we found many feathers with nest materials. We found it difficult to identify bird species based on eggs and feathers.

None of the people we questioned have observed Eurasian red squirrel on Kunashiri Island. These people also told us that they had never seen Siberian flying squirrel on Kunashiri Island.

DISCUSSION

Although we set nest boxes in a natural forest of Kunashiri Island for two years, we did not find signs of Siberian flying squirrels or small Japanese field mice. No inhabitant of Kunashiri Island has ever observed Eurasian red squirrel and Siberian flying squirrel on Kunashiri Island. Therefore, these three arboreal small mammal species are probably not present on Kunashiri Island. Although we did not look for these species in the other parts of Kunashiri Island, we do not expect to find these species, because none of the people we interviewed have seen these species.

Velizhanin [24] reports that during glaciation, animals resistant to cold should have survived on Kunashiri Island, but many forest mammals, such as Siberian flying squirrel, Eurasian red squirrel, small Japanese field mouse, sika deer, and raccoon dog, may have not survived on Kunashiri Island, due to reduction of forest environments. Kostenko et al. [14] reviewed the historical biogeography of Kunashiri Island’s fauna. Many mammal species may have immigrated from Hokkaido to Kunashiri Island when the islands were connected due to lower sea levels in the Pleistocene. Brown bear and red fox may have immigrated from Hokkaido to Kunashiri by using drift ice [14]. After separation of the islands, many surviving forest species may have become extinct on Kunashiri Island.

Environmental reasons for their extinction include cold temperatures and resource limitations. Severe forest reduction may have been the most important environmental change. Mammal species well adapted to forest environments could become extinct on Kunashiri Island during glaciations. Extant terrestrial small mammals on this island such as Siberian chipmunk (Tamias sibiricus) and large Japanese field mouse (Apodemus speciosus) are not arboreal species (Table 1). Therefore, our results support the scenario proposed by Velizhanin [24].

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国後島における陸棲哺乳類の動物地理学：寒帯域小島嶼環境に樹上性小型哺乳類は生息するのか？

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要約
北海道の北東部に位置する国後島において，北海道に広く分布する樹上性の 3 種の小型哺乳類（タイルクモモンガ Pteromys volans, ヒメネズミ Apodemus argenteus, キタリス Sciurus vulgaris）の分布調査を行った。タイルクモモンガおよびヒメネズミの生息を確認するため，国後島の南部に位置する寒帯性の針広混交天然林に 30 個の木製巣箱を 2 年間（2013年 7 月～2015年 8 月）設置した。加えて，2012年 7 月には，キタリスを目撃した経験の有無について 30 名の島民を対象にアンケート調査を実施した。巣箱調査の結果，タイリクモモンガおよびヒメネズミの個体或は巣材等の痕跡は一切観察されず，アンケート調査の結果でもキタリスを目撃したことがある島民はいなかった。国後島におけるこれら 3 種の分布記録はこれまで無かったが，本島でこれまでに用いられなかった巣箱調査法によってもタイリクモモンガ・ヒメネズミが確認できなかったことから，本島には樹上性小型哺乳類が生息しないことが改めて示唆された。更新世氷期に生じたと考えられる国後島内の森林の縮小は，これら 3 種を含む森林性哺乳類にとって生存の可否を決定づける重要な環境変化であり，森林の縮小に伴い森林環境によく適応した哺乳類種は絶滅したものかもしれない。

キーワード：ヒメネズミ，巣箱，更新世，タイリクモモンガ，キタリス

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