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EFFECT OF DIFFERENT SOIL HORIZONS ON DISTRIBUTION OF *SOREX* SPECIES IN HOKKAIDO, JAPAN

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To resolve effects of different soil horizons on distribution of two sympatric shrew species (*Sorex unguiculatus* and *S. gracillimus*) in Hokkaido, Japan, we compared their abundances between two different habitats: forest with litter rich soil (O layer-rich soil) and forest with humus layer rich soil (A layer-rich soil). Additionally, we compared arthropods species biomass between these habitats. *Sorex unguiculatus* feeds on insects and earthworms above and below ground, but *S. gracillimus* mainly feeds on insects above ground. Therefore, we expected that *S. unguiculatus* is commonly found in both forests, and *S. gracillimus* mainly habits the forest with O layer-rich soil. Our results supported the expectation. In the forest with O layer-rich soil, numbers of *S. unguiculatus* were significantly different from that of *S. gracillimus* in 2008, but were not in 2009. In the forest with A layer-rich soil, numbers of *S. unguiculatus* were significantly greater than that of *S. gracillimus*. To understand distribution patterns of *Sorex* species, evaluating soil conditions related to their niche should be more important than evaluating prey abundances.

Key words: *Sorex gracillimus*, *Sorex unguiculatus*, semi-fossorial, terrestrial, soil horizon.

INTRODUCTION

Mammalian species occurring sympatrically often share their niche to reduce serious competition for resources, showing 'competitive release' of each species (e.g., Feldhamer *et al*. 2004). For instance, in the tropical forest of Borneo Island, some tree squirrel species share arboreal niches: the Prevost's squirrel *Callosciurus prevostii* (Desmarest, 1822) and the giant squirrel *Ratufa affinis* (Raffles, 1821) feed high in the canopy, but the plantain squirrel *Callosciurs notatus* (Boddaert, 1785) and the horse-tailing squirrel *Sundasciurus hippurus* (I. Geoffroy, 1831) feed mainly in the lower and middle forest level (MacKinnon *et al*. 1996). In the same area, the niche used by diurnal tree squirrel species is successfully used by nocturnal flying squirrel species (MacKinnon *et al*. 1996). In the North America, two species of chipmunk, *Tamias dorsalis* Baird, 1855 and *T. umbrinus* J. A. Allen, 1890, are found at all elevations, when only one species occupies the mountain; they co-occurs, when *T. dorsalis* and *T.*

umbrinus occupy lower and higher elevations, respectively (HALL 1948). Thus, sharing niches play an important role for maintaining biodiversity in forests.

Sorex species are widely distributed in the arctic and temperate parts of the Northern Hemisphere (HUTTERER 2005). On Hokkaido Island, Japan (Fig. 1), there are four *Sorex* species: Eurasian least shrew *Sorex minutissimus* Zimmermann, 1780, Laxmann's shrew *S. caecutiens* Laxmann, 1788, long-clawed shrew *S. unguiculatus* Dobson, 1890 and slender shrew *S. gracillimus* Thomas, 1907 (OHDACHI *et al*. 2009). Of them, *S. unguiculatus* and *S. gracillimus* occur sympatrically in mountainous forests (OHDACHI & MAEKAWA 1990, YOKOHATA 1998). *Sorex unguiculatus* uses both terrestrial and fossorial niches (OHDACHI *et al*. 2009), feeding on insects and earthworms above and below ground (OHDACHI 1995*a, b*, YOSHINO & ABE 1984). This is largest *Sorex* species in Hokkaido: weight is about 15.3 g in male and 12.1 g in female; total length is about 133.7 mm in male and 132.7 mm in female (OHDACHI *et al.* 2009). *Sorex gracillimus* mainly uses a terrestrial niche, feeding on terrestrial insects, but not earthworms (OHDACHI 1995*b*). This is small size *Sorex* species in Hokkaido: weight is about 4.5 g in male and 4.4 g in female; total length is about 101.1 mm in male and 103.5 mm in female (OHDACHI *et al.* 2009). In Hokkaido's forests, the brown forest soil is well developed (ANZAI 2001). In this soil, the litter interception (O layer) and humus layer (A layer) are common, and provide food resources, such as insects, spiders, and earthworms. Many terrestrial arthropods, such as arachnids and isopods, are more abundant in the O layer than in the A layer (e.g., WATANABE 1969, KANEKO 2007); earthworms are found in both O and A layers (e.g., KITAZAWA 1973).

Therefore, the A and O layers may affect habitat use by *S. gracillimus* and *S. unguiculatus* in Hokkaido's forests. There are some studies analyzing shrew habitat and niche (e.g., OHDACHI 1995*a, b*, CHURCHFIELD *et al*. 1997, 1999, BRANNON 2000, CHURCHFIELD & RYCHLIK 2006), but none on include soil characteristics. Since *S. gracillimus* mainly feeds on terrestrial arthropods (OHDACHI 1995*a, b*), the O layer may be important habitat. Since *S. unguiculatus* feeds on earthworms underground, we may find this species in both O and A layers. Here, we propose the hypothesis that *S. gracillimus* mainly inhabits the forest with O layer-rich soil, and *S. unguiculatus* is commonly found in both the forest with O layer-rich soil and the forest with A layer rich soil. To test this hypothesis, we compared population densities of *S. gracillimus* and *S. unguiculatus* in both forests. Additionally, we comparatively investigated arthropods species biomass in both different forests. Here, we give preliminary results on the relationship between *Sorex* species distribution and soil characteristics.

MATERIALS AND METHODS

Study sites

We set two study sites (A and B) in the Daisetuzan National Park, Shikaoi, Hokkaido, Japan (Fig. 1). The elevation (819 m) of site A (43°15′N, 143°5′E) is similar to that (902 m) of site B (43°14′N, 143°5′E). The distance between sites was around 1.5 km. Therefore, we ignored the effects of temperature and humidity conditions on *Sorex* distribution patterns. *Sorex gracillimus* does not occur in lowlands because of niche competition with *S. caecutiens* (Yokohata 1998). Therefore, we selected these two sites in the present study.

Pre-examination of soil environments

We examined the soil conditions of the two study sites. Since our goal was to examine the distribution patterns of two *Sorex* species in A layer-rich soil forest and O layer-rich soil forest, we needed to ensure the soils had essentially similar chemical and physical properties.

We checked soil type and thickness of A and O layers. We also examined basic chemical properties: pH (H_2O), pH (KCl), electric conductivity (EC), and carbon (C) content. Soil types of both sites were classified as brown forest soil (Forest Soil Division 1976). This type is common in the forest land of Japan (e.g., Imaya *et al*. 2002). We found moderately moist brown forest soil and slightly dry brown forest soil in sites A and B, respectively. Except for thickness of A and O layers and EC value, soil conditions of two sites were essentially similar (data not shown). Sites A and B had comparatively more A layer soil and O layer soil, respectively. Water-soluble ions are generally produced with decomposition of organic matter (Forest Soil Research Society 1982). Since organic matter are smoothly

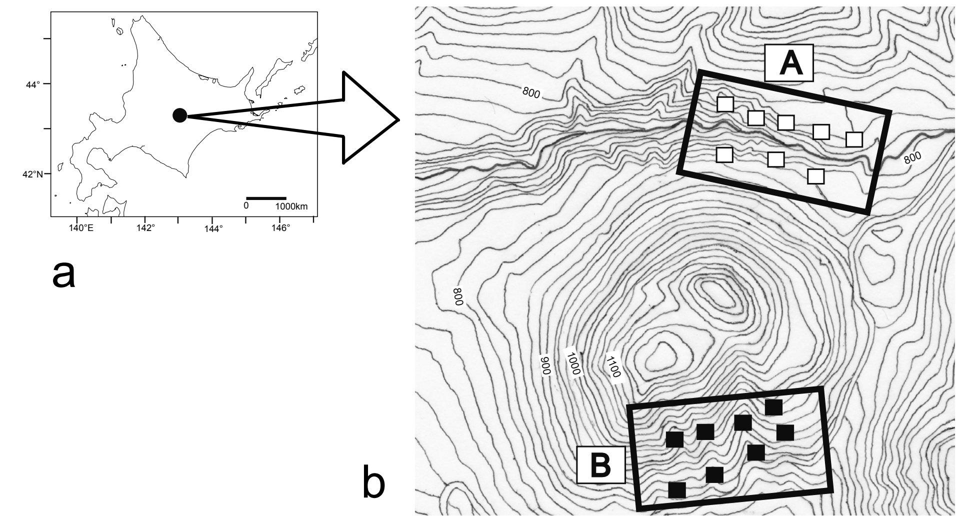

Fig. 1. a) Study area (Daisetuzan National Park, Shikaoi, Hokkaido, Japan) and b) two study sites (A and B) set in the area; closed and open small squares indicate transects in site A and site B, respectively.

decomposed in a developed A layer, the EC should be higher at site A, and was higher. Therefore, we concluded that two study sites differed in only soil layer; making them suitable for testing the relationship between soil layer and *Sorex* distribution.

Capture of Sorex *shrews*

We randomly set eight transects in each study site; the distances between transects were around 50–100 m. Each transect had an area of around 250 m^2. From June to August in 2008 and 2009, we randomly set 40 pit-fall traps in each transect. In each month, we trapped for two nights, and we checked all traps once per day. The depth and diameter of each pit-fall trap were 15 cm and 9 cm, respectively. *Sorex* individuals captured, which almost were not alive, were identified to species according to ABE *et al*. (2005). In each study year, between two study sites, we compared number of individuals in each *Sorex* species with a Mann-Whitney *U*-test.

Capture of terrestrial arthropods

To evaluate food resources for *Sorex* species in each study site, we used pit-fall traps as mentioned above. From June to August in 2008 and 2009, we randomly set 40 pit-fall traps in each transect for 4 days per month, and we checked all traps only last day. When *Sorex* species were accidentally captured in the pit-fall traps, we did not include the data into number of *Sorex* species. We categorized terrestrial arthropods into five groups (coleopterans, arachnids, centipedes, isopods and larvae) according to OHDACHI (1995*b*) and TIMOTHY and GERALD (1997). In each study year, between study sites, we compared total number of individuals in each group with Mann-Whitney *U*-test, using JMP version 8.02 (SAS INSTITUTE INC. 2008) with a significance level of 1%.

RESULTS

In 2008, in Site A, we captured 48 *S. unguiculatus* and 10 *S. gracillimus*. The average numbers with standard deviation per transect are shown in Table 1. There were significantly more *S. unguiculatus* ($z = -3.340$, $d.f. = 7$, $P < 0.001$). In 2008, in Site B, we captured 39 *S. unguiculatus* and 23 *S. gracillimus*. There were

Table 1. Mean numbers of two *Sorex* species captured in two study sites in Hokkaido, Japan in 2008 and 2009.

		Site A		Site B				
Year	Species	Mean	SD	Mean	SD	*d.f.*	*z*-value	*P*
2008	*S. unguiculatusi*	6.00	2.78	4.88	1.64	7	–0.488	0.625 (ns)
	S. gracillimus	1.25	1.17	2.88	1.46	7	2.084	<0.05
2009	*S. unguiculatusi*	4.50	0.93	3.25	0.71	7	–2.418	<0.05
	S. gracillimus	0.88	0.64	2.38	0.92	7	2.853	<0.001

Table 2. Mean numbers of arthropods species captured in two study sites in Hokkaido, Japan in 2008 and 2009.

Year	Arthropods	Site A		Site B				
		Mean	SD	Mean	SD	*d.f.*	*z*-value	*P*
2008	Coleopteran	409.63	77.60	933.88	145.89	7	3.308	<0.001
	Arachnids	24.25	4.53	33.63	7.52	7	2.368	<0.05
	Centipedes	6.63	2.45	20.63	3.11	7	3.318	<0.001
	Isopods	12.88	5.79	68.50	9.97	7	3.308	<0.001
2009	Coleopteran	343.75	45.25	702.00	49.20	7	3.311	<0.001
	Arachnids	15.00	5.98	24.63	7.95	7	2.208	<0.05
	Centipedes	5.75	1.98	19.25	4.10	7	3.320	<0.001
	Isopods	8.88	2.59	61.00	12.22	7	3.323	<0.001

significantly more *S. unguiculatus* ($z = -2.172$, $d.f. = 7$, $P < 0.05$). In 2009, in Site A, we captured 36 *S. unguiculatus* and 7 *S. gracillimus*. There were significantly more *S. unguiculatus* ($z = -3.381$, $d.f. = 7$, $P < 0.001$). In 2009, in Site B, we captured 26 *S. unguiculatus* and 19 *S. gracillimus*. Number of *S. unguiculatus* was not significantly different from that of *S. gracillimus* ($z = -1.877$, $d.f. = 7$, $P > 0.05$).

Between two sites, number of *S. unguiculatus* was not significantly different in 2008 (Table 1). In 2009, however, there were significantly more at Site A than Site B ($P < 0.05$) (Table 1). In both years, Site B had significantly more *S. gracillimus* than Site A ($P < 0.05$ in 2008; $P < 0.001$ in 2009) (Table 1).

In 2008, we captured 3,233 coleopterans, 194 arachnids, 53 centipedes, 103 isopods and 14 larvae in Site A and 7,471 coleopterans, 269 arachnids, 165 centipedes, 548 isopods, and 28 larvae in Site B. In 2009, we captured 2,750 coleopterans, 120 arachnids, 46 centipedes, 71 isopods and 4 larvae in Site A and 5,616 coleopterans, 167 arachnids, 154 centipedes, 488 isopods and 11 larvae in Site B. The average numbers with standard deviation per transect are shown in Table 2. Due to small numbers, we excluded larvae from our statistic analysis. In both years, between two study sites, numbers of arthropods in Site B were significantly larger than in Site A: coleopterans ($P < 0.001$), arachnids ($P < 0.05$), centipedes ($P < 0.001$) and isopods ($P < 0.001$) (Table 2).

DISCUSSION

Number of *Sorex unguiculatus* did not differ between two study sites in 2008, although arthropod resources in Site B were much more than in Site A. In 2009, the number of *S. unguiculatus* in Site A was significantly larger than that in Site B, although Site B had many more arthropod resources than in

Site A. Data from 2009 indicate this species may prefer A layer-rich forest to O layer-rich forest. *Sorex unguiculatus* inhabited both O and A layer-rich forests, but was not only affected by richness of arthropod resources. Since the semi-fossorial *S. unguiculatus* feeds on many kinds of soil animals, such as earthworms and arthropods, this species should occur in both O and A layer-rich forests. In addition, to use soil animals living under ground, this species may prefer to A layer-rich forest.

There were significantly more *Sorex gracillimus* in Site B than in Site A. These results could support our hypothesis. We also found that arthropods resources in Site B were much greater than in Site A. The O layer-rich soil could provide suitable habitat to arthropods (e.g., KITAZAWA 1973, KANEKO 2007). Therefore, *S. gracillimus* could essentially prefer to O layer-rich forest. This habitat would provide more food resources for *S. gracillimus*.

We did not recognize niche sharing of the two different soil environments by these two *Sorex* species. Both species do occur sympatrically, but *Sorex unguiculatus* inhabits in both O and A layer-rich forests, and *S. gracillimus* seems to prefer O layer-rich forest. Therefore, *S. unguiculatus* is expected to be more dominant when competing for the niche as reported by YOKOHATA (1998). Our results, however, suggest that *S. gracillimus* may occur in O-rich forest, irrespective of presence of *S. unguiculatus*. Therefore, the distribution of *S. gracillimus* may be more restricted by the development of the O soil layer than presence of *S. unguiculatus.*

BUTTERFIELD *et al*. (1981) and YALDEN (1981) reported that abundances of *S. araneus* Linnaeus, 1758 and *S. minutus* Linnaeus, 1766 in Europe were related to the abundance of their principle prey. CHURCHFIELD *et al*. (1997) reported that, in the Siberian taiga, there was no overall correlation between abundance of shrews and invertebrate prey, but that flood-plain habitats supported the greatest abundance and species richness of shrews and highest densities and biomass of prey. To understand the distribution patterns of *Sorex* species, evaluation of habitat factors such as the O soil layer may be more important than study of prey abundances. In the further study, it needs to resolve several factors at the same time in detail.

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REFERENCES

Abe, H., Ishii, N., Itoo, T., Kaneko, Y., Maeda, K., Miura, S. & Yoneda, M. (2005) *A guide to the mammals of Japan*. Tokai University Press, Kanagawa, 206 pp.

Anzai, T. (2001) [Classification and investigation of soils.] Pp. 93–108. *In:* Inubushi, K. & Anzai, T. (eds): [*Introduction to soil science.*] Asakura Publishing, Co., Ltd., Tokyo. [in Japanese]

Brannon, M. P. (2000) Niche relationships of two syntopic species of shrews, Sorex fumeus and S. cinereus, in the southern Appalachian mountains. *Journal of Mammalogy* **81**: 1053–1061.

Butterfield, J., Coulson, J. C. & Wanless, S. (1981) Studies on the distribution, food, breeding biology and relative abundance of the pygmy and common shrews (Sorex minutus and S. araneus) in upland areas of northern England. *Journal of Zoology (London)* **195**: 169–180.

Churchfield, S., Nesterenko, V. A. & Shvarts, E. A. (1999) Food niche overlap and ecological separation amongst six species of coexisting forest shrews (Insectivora: Soricidae) in the Russian Far East. *Journal of Zoology (London)* **248**: 349–359.

Churchfield, S. & Rychlik, L. (2006) Diets and coexistence in Neomys and Sorex shrews in Bialowieza forest, eastern Poland. *Journal of Zoology (London)* **269**: 381–390.

Churchfield, S., Sheftel, B. I., Moraleva, N. V. & Shvarts, E. A. (1997) Habitat occurrence and prey distribution of a multi-species community of shrews in the Siberian taiga. *Journal of Zoology (London)* **241**: 55–71.

Feldhamer, G. A., Drickamer, L. C., Vessey, S. H. & Merritt, J. F. (2004) *Mammalogy: adaptation, diversity, and ecology. 2nd ed.* The McGraw-Hill Companies, Inc., New York, 550 pp.

Forest Soil Division (1976) Classification of forest soil in Japan (1975). *Bulletin of the Government Forest Experiment Station* **280**: 1–28. [in Japanese with an English summary]

Forest Soil Research Society. (1982) [*Method to investigate forest soil and its properties.*] Rinyakouseikai, Tokyo, 328 pp. [in Japanese]

Hall, E. R. (1948) *Mammals of Nevada*. University of California Press, Berkeley, 736 pp.

Hutterer, R. (2005) Order Soricomorpha. Pp. 220–311. *In:* Wilson, D. E. & Reeder, D. M. (eds): *Mammal species of the world: a taxonomic and geographic references, 3rd ed*. The Johns Hopkins University Press, Baltimore, Maryland.

Imaya, A, Morisada, K. & Ohta, S. (2002) Chemical properties and classification of Japanese brown forest soils derived from various parent materials. Pp. 1–10. *In: 17*th *World Congress of Soil Science, Bangkok, Thailand*.

Kaneko, N. (2007) [*Introduction to soil ecology: biodiversity of soil animals and their ecological functions*.] Tokai University Press, Hadano, Japan, 199 pp. [in Japanese]

Kitazawa, Y. (1973) [*Ecology of soil animals*.] Kyoritsu Shuppan Co., Ltd., Tokyo, 158 pp. [in Japanese]

MacKinnon, K., Hatta, G., Halim, H. & Mangalik, A. (1996) *The ecology of Indonesia, series 3: The ecology of Kalimantan, Indonesian Borneo*. Periplus Editions Ltd., Singapore, 802 pp.

Ohdachi, S. (1995*a*) Diets and abundances of three sympatric shrew species in northern Hokkaido. *Journal of Mammalogical Society of Japan* **20**: 69–83.

OHDACHI, S. (1995*b*) Burrowing habitats and earthworm preferences of three species of Sorex in Hokkaido. *Journal of Mammalogical Society of Japan* **20**: 85–88.
OHDACHI, S. D., ISHIBASHI, Y., IWASA, M. A. & SAITOH, T. (2009) *The wild mammals in Japan*. Shoukadoh Book Sellers, Kyoto, 544 pp.
OHDACHI, S. & MAEKAWA, K. (1990) Geographic distribution and relative abundance of four species of soricine shrews in Hokkaido, Japan. *Acta Theriologica* **35**: 261–267.
SAS INSTITUTE INC. (2008) *Introductory guide. Japanese Edition, JMP8*. SAS Institute Inc., Cary, NC.
TIMOTHY, S. M. & GERALD, L. S. (1997) Masked shrew (Sorex cinereus) abundance, diet and prey selection in an irrigated forest. *American Midland Naturalist* **138**: 268–275.
WATANABE H. (1969) A study of the vertical distribution of soil macro-animals in a Cryptomeria plantation, a natural mixed forest of Cryptomeria, beech and deciduous oak; and a grassland on different soil types. *Japanese Journal of Ecology* **19**: 56–62.
YALDEN, D. (1981) The occurrence of the pygmy shrew Sorex minutus in moorland, and the implications for its presence in Ireland. *Journal of Zoology (London)* **195**: 147–156.
YOKOHATA, Y. (1998) [Ecology of soricine shrews in Hokkaido, Japan.] Pp. 268–274. *In:* ABE, H. & YOKOHATA, Y. (eds): [*Natural history of insectivores.*] Hibakagakukyouikushinkoukai, Yamagata, Japan. [in Japanese].
YOSHINO, H. & ABE, H. (1984) Comparative study on the foraging habits of two species of soricine shrews. *Acta Theriologica* **29**: 35–43.

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