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Difference in diets between two species of soricine shrews, *Sorex unguiculatus* and *S. caecutiens*

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Diets of *Sorex unguiculatus* Dobson, 1890 and *S. caecutiens* Laxmann, 1788, two dominant soricine shrews in most habitats in Hokkaido (Japan) were examined. Results showed that *Lumbricidae*, adult *Coleoptera* and plant materials were consumed by *S. unguiculatus*, whereas *S. caecutiens* fed on mainly adult *Coleoptera*, *Araneae*, and *Lepidoptera* larvae. This result indicates that the former exploits underground microhabitats, while the latter forages for food on the ground surface. Since dominant components in the diet of *S. unguiculatus* for both the survey areas were similar regardless of the coexistence of *S. caecutiens*, we concluded that exploitation of underground microhabitats by *S. unguiculatus* is due to its habitat preference rather than avoidance of interspecific competition with related species. Diets of several soricine shrews in different geographic regions were compared, and the results suggest that larger shrews are more subterranean and thus body size and microhabitat utilization may have evolved as interrelated traits among soricine shrews.

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Introduction

Four species of soricine shrews are distributed throughout Hokkaido, Japan. Two of them, *Sorex unguiculatus* Dobson, 1890 and *S. caecutiens* Laxmann, 1788, are dominant in most of the habitats. These two species have been frequently collected together, and are living sympatrically in Hokkaido (Maekawa 1981). Morphological characteristics (larger fore feet and shorter tail in the *S. unguiculatus*) suggest that this species has an adaptation for digging and the *S. caecutiens* for feeding on ground surfaces (Abe 1968). Laboratory feeding tests also showed that *S. unguiculatus* tended to utilize a deep underground habitat and foods, while *S. caecutiens* often moved and fed on the ground surface (Yoshino and Abe 1984). The dominant component in *S. caecutiens* diet was *Araneae*, whereas *S. unguiculatus* mainly consumed *Lumbricidae* (Abe 1968). These observations suggest that there could be a microhabitat separation between them and thus reducing competition between them to a minimum.

In this paper, diets of *S. unguiculatus* and *S. caecutiens* and potential food availability are reported, and competition for foods between these species is assessed by comparing diets of *S. unguiculatus* in two habitats where the potential of competition between the two species of shrews differs. Finally, diets of several soricine shrews in different geographic regions are compared.

Study areas and methods

Trapping

Trapping was carried out in two different areas in Hokkaido, Japan: in scrub area at Yufutu, Tomakomai between April and November, 1978; and in a wind-shelterbelt at Tonden in the suburbs of Sapporo between April and October, 1981. In Yufutu, dominant plants are *Alnus japonica*, *Fraxinus mandshurica*, and *Spiraea salicifolia*. The ground was mainly covered with *Scirus* sp. In Tonden, the dominant plant is *Fraxinus mandshurica*. The ground flora included *Solidago altissima*, *Artemisia montana*, and *Sasa senanensis*. The distance between the two areas is about 65 km.

Pitfall traps (14 cm in diameter and 27 cm deep) were used to capture shrews for observing their stomach contents. Each sampling period was for 3 – 5 consecutive days every month. Fifteen – thirty traps were made in a lines at intervals of 5 – 10 m in the survey area, and checked daily. The sites for traps were changed monthly. In order to retain the food in the shrew's stomach, they must be killed immediately by drowning. This was accomplished by filling each pitfall trap one-third full with water. In October and November, some antifreeze solution was also added.

Invertebrate sampling

In Tonden, 30 plastic cups (80 mm in diameter) were set on the ground near capturing sites for 3 consecutive days almost every month to sample invertebrates which moved on the ground surface. Ten of the cups were buried 5 m apart in a straight line and filled with a little ethanol solution. Sessile invertebrates in the soil were sampled using soil cores (25 cm square and 35 cm deep). Five quadrats were randomly selected in the survey area and samples from these quadrats were taken using a shovel during each shrew-trapping period. Plastic cups and soil cores were collected and taken to the laboratory. The soil cores were transfered a little at a time into a steep-sided tray for sorting by hand. All invertebrates except soil mites and springtails were identified, divided into major higher taxa and counted. In Yufutu, plastic cups containing an ethanol solution were set on the ground to collect standard samples of invertebrate for identification of shrew's stomach contents.

Diet analysis

Each specimen was dissected to observe its stomach content. The stomach was opened in a Petri dish and stomach contents were checked using a dissecting microscope ($\times 10 - 20$). Segments in the stomach contents were identified by reference to invertebrates collected from the survey areas and by taxonomic keys. Invertebrates found in the stomach contents were often broken into small segments making it difficult to estimate the number of a certain invertebrate species which had been consumed, and also to identify the species name. Only the higher taxon to which the samples belong could be determined. The frequency in which a certain taxon was observed in the stomachs examined is shown in tables.

Results

Invertebrate sampling

Table 1 shows the number of each invertebrate taxon and its frequency of occurrence in soil cores. The most numerous major taxa were *Lumbricidae*, *Chilopoda* (most of them are *Geophilida*), and *Coleoptera* larvae. *Lumbricidae* could be found in over 60% of all samples collected. Table 2 shows the number of each taxon and its frequency of occurrence in plastic cups. *Lumbricidae* and *Chilopoda* were rarely caught in plastic cups. Adult *Hymenoptera* (ants), *Diplopoda*, adult *Coleoptera*, and *Araneae* formed the major components of the surface-active fauna during this survey period. The first three taxa showed peak numbers in July. *Lepidoptera* larvae and *Opilioneae* were not found in any of the soil cores. The high percentage of *Lumbricidae* found in soil cores was similar for every survey month, but several taxa (*e.g. Diplopoda*, adult *Hymenoptera*, *Coleoptera* larvae, and *Amphipoda*) showed a marked seasonal change in numbers.

Table 1. Number of major invertebrate taxa in soil cores and their percent frequency of occurrence.

Taxa	No. of individuals (% occurrence)						
	Apr.	Jun.	Jul.	Aug.	Sep.	Oct.	Total
Lumbricidae	271 (87.7)	40 (26.1)	78 (35.2)	42 (70.0)	63 (54.3)	151 (67.7)	645 (59.6)
Mullusca (slug)	4 (1.3)	–	–	–	–	–	4 (0.4)
Chilopoda	5 (1.6)	40 (26.1)	72 (32.6)	11 (18.3)	31 (26.7)	24 (10.8)	183 (16.9)
Diplopoda	5 (1.6)	27 (17.6)	18 (8.1)	–	1 (0.9)	1 (0.5)	52 (4.8)
Isopoda	2 (0.6)	39 (25.5)	5 (2.3)	–	–	3 (1.3)	49 (4.5)
Amphipoda	–	–	–	1 (1.7)	–	–	1 (0.1)
Araneae	–	–	1 (0.5)	1 (1.7)	–	1 (0.5)	3 (0.3)
Coleoptera larvae	11 (3.6)	1 (0.7)	7 (3.2)	–	17 (14.7)	40 (17.9)	76 (7.0)
Coleoptera adults	2 (0.6)	4 (2.6)	19 (8.6)	5 (8.3)	3 (2.6)	3 (1.3)	36 (3.3)
Diptera larvae	5 (1.6)	2 (1.3)	4 (1.8)	–	–	–	11 (1.0)
Hemiptera adults	4 (1.3)	–	–	–	–	–	4 (0.4)
Hymenoptera adults	–	–	17 (7.7)	–	1 (0.9)	–	18 (1.7)
Total	309	153	221	60	116	223	1082

Comparison of the two survey areas

Two hundred twenty-six shrews collected in Yufutu, Tomakomai consisted of 139 were *S. caecutiens* (61.5%), 85 *S. unguiculatus* (37.6%), and 2 *S. gracillimus* (0.9%). 162 shrews collected in Tonden, Sapporo consisted of 153 *S. unguiculatus* (94.4%) and 9 *S. caecutiens* (5.6%). The percentage of *S. unguiculatus* is quite different between the two areas.

Table 2. Number of major invertebrate taxa collected in plastic cups and their percent frequency of occurrence.

Taxa	No. of individuals (% occurrence)						
	May	Jun.	Jul.	Aug.	Sep.	Oct.	Total
Lumbricidae	8	5	1	4	2	7	27
	(1.3)	(0.5)	(0.04)	(0.9)	(0.4)	(2.5)	(0.5)
Mullusca (slugs)	40	6	12	3	8	5	74
	(6.4)	(0.6)	(0.4)	(0.7)	(1.6)	(1.8)	(1.3)
Chilopoda	15	10	12	–	4	1	42
	(2.4)	(1.0)	(0.4)		(0.8)	(0.3)	(0.8)
Diplopoda	120	72	993	9	10	26	1230
	(19.1)	(7.4)	(35.8)	(2.1)	(2.0)	(9.3)	(22.0)
Isopoda	82	26	61	2	7	3	181
	(13.0)	(2.7)	(2.2)	(0.5)	(1.4)	(1.1)	(3.2)
Amphipoda	–	40	121	16	11	31	219
		(4.1)	(4.4)	(3.6)	(2.2)	(11.1)	(3.9)
Araneae	207	58	47	35	39	92	478
	(32.9)	(5.9)	(1.7)	(8.0)	(7.9)	(32.9)	(8.5)
Opilioneae	32	94	62	1	10	–	199
	(5.1)	(9.6)	(2.2)	(0.2)	(2.0)		(3.6)
Coleoptera larvae	1	14	303	10	10	4	342
	(0.2)	(1.4)	(10.9)	(2.3)	(2.0)	(1.4)	(6.1)
Coleoptera adults	95	203	321	144	81	48	892
	(15.1)	(20.7)	(11.6)	(32.8)	(16.4)	(17.1)	(15.9)
Diptera larvae	1	–	–	–	1	–	2
	(0.2)				(0.2)		(0.04)
Hemiptera adults	16	6	17	5	2	4	50
	(2.5)	(0.6)	(0.6)	(1.1)	(0.4)	(1.4)	(0.9)
Hymenoptera adults	12	431	797	206	301	41	1788
	(1.9)	(44.0)	(28.7)	(46.9)	(60.8)	(14.6)	(32.0)
Lepidoptera larvae	–	13	27	1	1	2	44
		(1.3)	(1.0)	(0.2)	(0.2)	(0.7)	(0.8)
Other insects	–	1	–	3	8	16	28
		(0.1)		(0.7)	(1.6)	(5.7)	(0.5)
Total	629	979	2774	439	495	280	5596

Diet of *S. caecutiens*

From 139 specimens collected in Yufutu, we were able to identify the stomach contents of 91 (65.5%). The frequency of each item in all the stomach samples of *S. caecutiens* is summarized in Table 3. *S. caecutiens* mainly consumed adult *Coleoptera*, *Araneae*, and *Lepidoptera* larvae throughout the survey period. The higher consumption of adult *Hymenoptera* by *S. caecutiens* in summer are related to the seasonal change of numbers in this taxon (see Table 2). These results indicate that *S. caecutiens* moves and forages on the ground surface.

Table 3. Percent frequencies of each taxon in the total stomach contents of *S. caecutiens*.

Taxa	Apr.+May +Jun. N=22	Jul. 15	Aug. 22	Sep. 14	Oct.+Nov. 18	Total 91
Lumbricidae	9.1	6.7	–	–	5.5	4.4
Mullusca (slugs)	–	–	–	–	5.5	1.1
Chilopoda	13.6	13.3	4.5	–	–	6.6
Araneae	45.5	26.7	40.9	14.3	72.2	41.8
Coleoptera larvae	50.0	–	4.5	14.3	5.6	16.5
Coleoptera adults	45.5	66.7	63.6	85.7	66.7	63.7
Hemiptera adults	–	6.7	–	–	16.7	4.4
Hymenoptera adults	4.5	13.3	50.0	21.4	16.7	22.0
Lepidoptera larvae	27.2	13.3	27.2	–	50.0	25.3
Lepidoptera adults	–	13.3	–	–	–	2.2
Odonata adults	–	–	–	–	5.6	1.1
Plants	18.1	33.3	13.6	14.3	11.1	17.6

The low frequency (only 4 individuals) of *Lumbricidae* in the diet of *S. caecutiens* suggests that this item is not important in the diet of this species. *Diplopoda*, which formed the major component of surface-active fauna was not consumed at all by *S. caecutiens*. This suggests that these animals could be distasteful to shrews (Crowcroft 1957, Rudge 1968, Pernetta 1976).

Diet of *S. unguiculatus*

From 238 specimens collected in both areas, we were able to identify the stomach contents of 168 (70.6%). Frequency of *S.unguiculatus* stomachs containing specified taxon in each area is summarized in Table 4. Dominant components in the diet of *S. unguiculatus* for the two survey areas were similar; *Lumbricidae*, plant materials, and adult *Coleoptera* were the highest frequencies in the prey category of both populations. However, there was a definite difference in diets of *S. unguiculatus* and *S. caecutiens*: *Araneae* which constituted the major food of *S. caecutiens* was hardly consumed by *S. unguiculatus*, and *Lumbricidae* which was the main component in *S. unguiculatus* diet was hardly consumed by *S. caecutiens*.

Although there is a possibility that the plant materials detected in the stomach of *S. unguiculatus* are not a reflection of direct plant-feeding habits, assuming that most of the plant materials originated from the guts of *Lumbricidae* which was consumed by the shrew (Pernetta 1976), the high frequency of plant materials in *S. unguiculatus* stomachs must be an important characteristic of its food habits.

Discussion

These finding about the diets of the two species are similar to that reported by Abe (1968). Abe reported that *Araneae* was frequently consumed by *S. caecutiens*, whereas *S. unguiculatus* mainly fed on *Lumbricidae*. Diet overlap between the two species is

Table 4. The percent frequencies of each taxon in the total stomach contents of *S. unguiculatus* in two different reas.

(a) Yufutu, Tomakomai

Taxa	Apr.+May +Jun. N=10	Jul. 13	Aug. 15	Sep.+Oct. +Nov. 14	Total 52
Lumbricidae	70.0	69.2	40.0	71.4	61.5
Mullusca (slugs)	–	–	6.7	–	1.9
Araneae	–	–	20.0	14.3	9.6
Coleoptera larvae	30.0	15.4	6.7	14.3	15.4
Coleoptera adults	–	38.5	33.3	42.9	30.8
Diptera larvae	10.0	30.8	6.7	–	11.5
Hemiptera adults	–	–	–	14.3	3.8
Hymenoptera adults	–	7.7	20.0	7.1	9.6
Lepidoptera larvae	10.0	15.4	–	–	5.8
Lepidoptera adults	–	7.7	–	–	1.9
Plants	40.0	92.3	66.7	57.1	65.4

(b) Tonden, Sapporo

Taxa	Apr. N=17	May 18	Jun. 19	Jul. 15	Aug. 12	Sep. 20	Oct. 15	Total 116
Lumbricidae	64.7	66.7	63.2	60.0	75.0	80.0	80.0	69.8
Chilopoda	–	5.6	5.3	–	–	–	13.3	4.3
Araneae	11.8	–	–	6.7	–	15.0	–	5.2
Coleoptera larvae	5.9	44.4	38.8	–	–	15.0	13.3	18.1
Coleoptera adults	29.4	22.2	26.3	80.0	58.3	15.0	26.7	34.5
Diptera larvae	–	5.6	5.3	–	–	5.0	–	2.6
Diptera adults	–	5.6	5.3	6.7	–	–	6.7	3.4
Hemiptera adults	11.8	11.1	5.3	–	–	–	–	4.3
Hymenoptera adults	5.9	11.1	10.5	20.0	–	–	–	6.9
Lepidoptera larvae	–	16.7	10.5	13.3	8.3	5.0	20.0	10.3
Plants	29.4	61.1	47.4	66.7	66.7	95.0	66.7	62.1

small. Furthermore, from invertebrate sampling, *S. caecutiens* is shown to feed on the ground surface fauna, while *S. unguiculatus* eat more burrowing animals. It is suggested that microhabitat separation between them exists (Abe 1968); *S. unguiculatus* exploited more subterranean microhabitats to obtain prey than *S. caecutiens*.

The present study also showed that diets of *S. unguiculatus* in the two different areas did not change even with coexistence of *S. caecutiens*. Consequently, exploitation of underground microhabitats by *S. unguiculatus* in a sympatric habitat could be explained by its habitat preference rather than avoidance of interspecific competition with related species. This conclusion is supported by its morphological specializations for digging (Abe 1968) and by the frequent observations of its digging behaviours in the laboratory (Yoshino and Abe 1984). The preference for underground microhabitat by *S. unguiculatus* can facilitate coexistence with related species (*S. caecutiens* or *S. gracillimus*) which mainly move and feed on the ground surface.

Table 5. Comparison of diets between several sorocine shrews in Britain, Ireland and Japan.

Species (approx. weight)	Objects of analysis	Prey category % occurrence (No./total examined)		References
		Araneae	*Lumbricidae*	
S. minutus (4g)	stomach and gut contents	54.6(71/130)	0.0(0/130)	Pernetta (1976)
	gut contents	34.8(114/327)	0.0(0/327)	Grainger and Fairly (1978)
	stomach contents	52.3(22/42)	0.0(0/42)	Butterfield *et al.* (1981)
	total	41.5(207/499)	0.0(0/499)	
S. caecutiens (7g)	stomach contents	35.9(42/117)	2.6(3/117)	Abe (1968)
	stomach contents	41.8(38/91)	4.4(4/91)	this study
	total	38.5(80/208)	3.4(7/208)	
S. araneus (7g)	gut contents	14.1(44/312)	39.2(124/312)	Rudge (1968)
	stomach and gut contents	54.9(118/215)	57.2(123/215)	Pernetta (1976)
	stomach contents	38.1(16/42)	47.6(20/42)	Butterfield *et al.* (1981)
	total	31.3(178/569)	46.9(267/569)	
S. unguiculatus (11g)	stomach contents	9.1(6/66)	40.9(27/66)	Abe (1968)
	stomach contents	6.0(11/168)	67.3(113/168)	this study
	total	7.3(17/234)	59.8(140/234)	

Sorex araneus and *S. minutus* are living sympatrically in various habitats throughout much of Europe (*e.g.* Croin Michielsen 1966, Pernetta 1976, 1977, Ellenbroek 1980, Yalden 1981, Butterfield *et al.* 1981, Churchfield 1984a, 1984b, Malmquist 1985, Dickman 1988). The reduction of competition between them also appears to operate through their microhabitat preferences (see Croin Michielsen 1966, Parnetta 1976, Ellenbroek 1980). Table 5 shows a diet comparison of several insectivorous mammals in Britain, Ireland, and Japan. Although the frequency of occurrence method is not directly quantitative, an approximate scale of importance can be constructed by containing large samples (Rudge 1968). The percent frequency of individuals whose stomachs and/or intestines contained *Araneae* (which is unique to prey category in ground surface microhabitat) or *Lumbricidae* (unique to underground microhabitat) of each species was utilized. Both *S. minutus* and *S. caecutiens* hardly consumed any *Lumbricidae*. This indicates that smaller soricine species in each geographic region can mainly utilize resources on the ground surface.

Churchfield (1980) and Dickman (1988) showed that *S. araneus* also has burrowing habits similar to those of *S. unguiculatus*. Furthermore, Abe (1983) concluded that these species have ecological equivalents in different geographic regions (see also Yoshino and Abe 1984). However, *S. unguiculatus* consumed more *Lumbricidae* and less *Araneae* than *S. araneus*, although the frequency of occurrence of each prey category differed between populations. This suggests that larger *S. unguiculatus* utilized underground microhabitats more often than smaller *S. araneus*.

The result of interspecific comparison suggests that larger shrews appear more subterranean (see Aitchison 1987, Dickman 1988) and thus body size and microhabitat utilization could have evolved as interrelated traits among soricine shrews. If this interrelationship between these variables is correct, we could expect a similar relationship between diets and body size for other soricine shrews.

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