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Original Article

Species composition and the vertical niche breadth of ground beetles (Carabidae, Brachinidae) in the Southern Japan Alps

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Abstract

Field studies were conducted in the Southern Japan Alps from June to September of 2001 in order to clarify the species composition and vertical distribution of ground beetles. Eleven survey sites ranging in altitude from 1000 m to 2600 m were selected at Mt. Senjo. In June of 2001, pitfall traps were set 3 times at survey sites from 1000 m to 1400 m in altitude, and from August to September of 2001, trap collection was carried out twice at altitudes from 1000 m to 2600 m. All traps were baited with a lactic acid beverage mixed with 70% ethyl alcohol. A total of 2337 individuals comprising 37 species of ground beetles of Carabidae and Brachinidae were collected in this study. The dominant species found in the June collections were *Pterostichus subovatus* (44.9% of the total) and *Leptocarabus procerulus* (38.6% of the total). The 4 most numerous species of the individuals collected in August and September were *Leptocarabus arboreus horioi, Trigonognatha aurescens, Pterostichus brunneipennis akaishicus* and *Synuchus cycloderus,* which represented 76.3% (1649 individuals) of the total collected. The vertical niche breadths of ground beetles were calculated using the data of the August and September collections. The 5 species which showed the highest values for niche breadth were *S. cycloderus, Pt. brunneipennis akaishicus, L. arboreus horioi, P. aeneola* and *Synuchus melantho. S. cycloderus* showed a wide vertical distribution from 1000 m to 2400 m and also showed the highest value of niche breadth. Species of high relative abundance had wide niche breadth though we found no relationship between niche breadth and relative abundance among species of low abundance. The correlation coefficient between niche breadth and mean altitude of the vertical distribution indicated a slightly positive relationship. We include a discussion of the selection of appropriate species to represent the mountainous environment.

Key words : Southern Japan Alps, Ground beetles, Vertical distribution, Pitfall trapping, Niche breadth

Introduction

Many researchers have studied the species composition, seasonal abundance and distribution of ground beetles in various habitats (Thiele, 1977; Luff, 1987; Suttiprapan *et al.*, 2003; French *et al.*, 2004; Siddiquee *et al.*, 2005), and ground beetles have been selected as indicator insects of various environments (Ishitani, 1996; Allegro and Sciaky, 2003) because of the requirements of wide distribution, sensitivity to environmental variation and a standard sampling method (pitfall trapping) (Dufrêne *et al.*, 1990; Sunose, 1992). Additionally, several endangered ground beetles are important species with respect to environmental impact assessment.

The environmental conditions of mountainous areas differ from those of non-mountainous areas not only in their altitude but also in their faunas, and there is great diversity in the insect species that live and procreate in various mountain habitats. Recently, the environments of high mountainous areas have been disturbed by human activity, such as the construction of a dam or road, and the overuse of famous beauty spots. Ground beetles show a strong relationship with environmental conditions and act as potential bioindicators of stability or the degree of ecosystem stress, provided that their relative abundance can be assessed (Allegro and Sciaky, 2003). However, there

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Mt. Senjo is located in the Southern Japan Alps, which extend across Nagano, Yamanashi and Shizuoka Prefectures in the middle part of Japan and are host to various kinds of alpine plants, wild animals and insects. In 1952, construction was begun on the South Alps forest road, which opened to the Kitazawa Pass through the national park of the Southern Japan Alps in 1980. Martin (1989, 1992) recorded approximately 200 species of beetles collected by pitfall traps at Mt. Senjo and Mt. Kaikomagadake; after Martin's studies, there have been some reports on ground beetles (Tahira, 1995; Morita, 1998) but no reports on species composition or abundance in this area. In 2004, several carabid species inhabiting only the area around Mt. Senjo were designated as endangered species (Nagano Nature Conservation Research Institute, 2004).

In the present study, in order to clarify the species composition and vertical distribution of ground beetles of Carabidae and Brachinidae in the Southern Japan Alps, field studies were conducted from June to September of 2001 for the purpose of selecting appropriate species to represent the mountainous environment.

Materials and Methods

Study sites

Eleven sites were selected at different altitudes on Mt. Senjo in the Southern Japan Alps. A map of the survey sites is shown in **Fig. 1**. Below 1500 m, deciduous broad-leaved trees were dominant, and coniferous trees including Marie's fir (*Abies mariesii*), silver fir (*Abies veitchii*) and Japanese hemlock (*Tsuga diversifolia*) were dominant from 1500 m to 2700 m; above 2700 m, the Japanese mountain stone pine (*Pinus pumila*) was dominant.

Pitfall trapping was conducted a total of 5 times from June to September of 2001 (**Table 1**). The high areas of Mt. Senjo were still covered with snow in June, and pitfall traps were therefore set only at survey sites from 1000 m to 1400 m. In the months of July to September, trap collections were carried out twice at altitudes ranging from 1000 m to 2600 m.

Study methods

Transparent plastic cups 13 cm deep with upper and lower diameters of 9 and 6 cm, respectively, were used as traps. All traps were baited with a lactic acid beverage (Calpis™, Calpis Co., Ltd., Tokyo, Japan) mixed with 70% ethyl alcohol as a preservative material necessary due to the long interval between setting the traps and collecting the insects. Each trap was placed into the ground and covered by a stone or a piece of wood. Covering the traps provided favorable shade for ground beetles, reduced evaporation of the ethyl alcohol and prevented excess rainwater and small mammals from entering the traps.

Seven pitfall traps were placed at each study site from 1000 m to 1400 m and 5 pitfall traps at each site above 1600 m. The survey dates and numbers of traps at each survey site are given in **Table 1**. The traps were sometimes destroyed by animals, so the number of traps upon collection was lower than the number initially set. The names and numbers of the species of ground beetles captured in the traps were recorded. In the present study, the name *Pristosia colpodoides* was regarded as a synonym of *Pristosia aeneola*.

Niche breadth

The niche breadth (B_i) of a species i with respect to a given environmental factor can be defined as follows (Kobayashi, 1995):

$$B_i = -\Sigma\, p_{ij} \cdot \ln p_{ij}$$

$$p_{ij} = n_{ij} \,/\, \Sigma\, n_{ij}$$

where p_{ij} is the proportion of individuals collected at the jth study site in the total sample of species i and n_{ij} is the number of trapped species i at the jth study site. In the present study, we calculated the niche breadth of ground beetles with respect to altitude using the survey data collected in August and September of 2001.

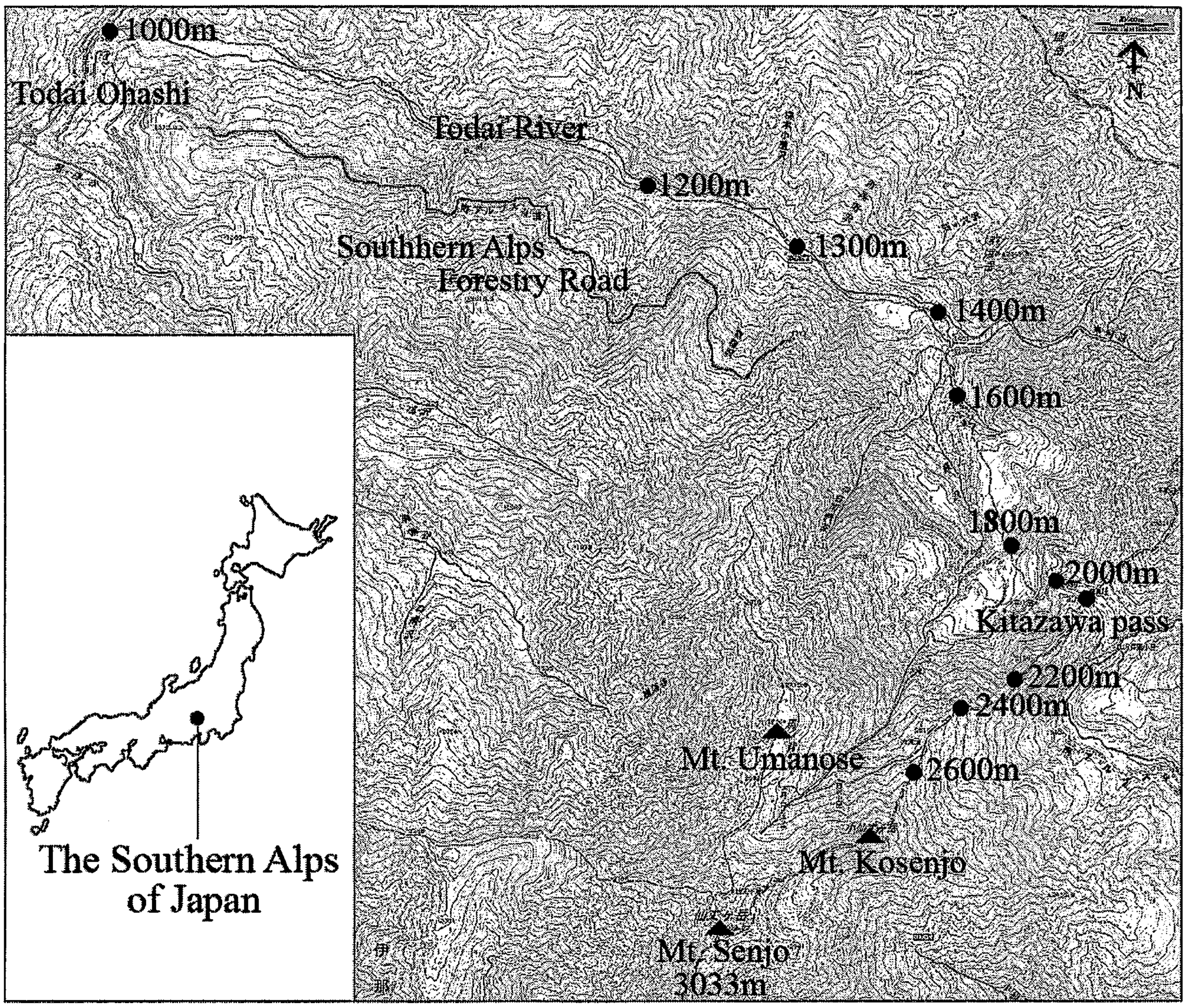

Fig. 1 Map of survey sites at altitudes from 1000 m to 2600 m on Mt. Senjo.

Table 1 Survey dates and the number of traps used at each survey site. Numbers in parentheses indicate the number of collected traps

Altitude of survey site		Survey date				
	Stting	6/1	6/8	6/23	7/14·15	8/15·16
	Collecting	6/8	6/23	7/15	8/15·16	9/16·17
1000 m		7(7)	7(5)	7(7)	7(5)	7(4)
1100 m		7(7)	7(7)	7(7)	7(7)	7(4)
1200 m		7(7)	7(7)	7(7)	7(5)	7(4)
1300 m		7(7)	7(7)	7(7)	7(2)	7(3)
1400 m		7(7)	7(7)	7(7)	7(7)	7(4)
1600 m		—	—	—	5(5)	5(2)
1800 m		—	—	—	5(5)	5(3)
2000 m		—	—	—	5(5)	5(3)
2200 m		—	—	—	5(5)	5(5)
2400 m		—	—	—	5(5)	5(3)
2600 m		—	—	—	5(5)	5(3)

Results

Species composition

A total of 2337 individuals comprising 37 species of ground beetles of Carabidae and Brachinidae were collected in the present study. **Table 2** shows the species and numbers of the ground beetles collected at the 5 survey sites at altitudes from 1000 m to 1400 m in June and July; a total of 176 individuals belonging to 18 species were caught. The dominant species were *Pterostichus subovatus* (79 individuals, 44.9% of the total) and *Leptocarabus procerulus* (68 individuals, 38.6% of the total). Most individuals of these two dominant species were caught at the survey site at 1300 m. The remaining sixteen species were represented by fewer than 5 individuals each.

Table 3 shows ground beetles captured in August and September at 11 survey sites at altitudes from 1000 m to 2600 m. A total of 2161 individuals comprising 29 species were collected. The 4 most numerous species were *Leptocarabus arboreus horioi, Trigonognatha aurescens, Pterostichus brunneipennis akaishicus* and *Synuchus cycloderus*, which together represented 76.3% (1649 individuals) of the total. The remaining 25 species were represented by fewer than 91 individuals each, including 13 species represented by fewer than 10 individuals each.

The numbers of captured individuals per trap of the 4 dominant species at each altitude are given in **Fig. 2.** *L. arboreus horioi* was collected at altitudes from 1600 m to 2600 m and showed a peak at 1800 m with higher numbers trapped in August than in September. The highest number of *T. aurescens* was collected at 2600 m in August. Many individuals of *Pt. brunneipennis akaishicus* were collected above 2400 m in August, but few in September. *S. cycloderus* was collected at the sites from 1300 m to 2400 m in August, and at 1000 m to 2200 m in September.

Vertical distribution

The total numbers of individuals and species collected at altitudes from 1000 m to 2600 m in August and September are shown in **Fig. 3.** More ground beetles were captured at high survey sites (above 1600 m) than at low sites (below 1400 m) in August and September, however, at survey sites from 1800 m to 2600 m, the number of captured beetles decreased in September. On the other hand, the number of

Table 2 Species and numbers of ground beetles collected at 5 survey sites from 1000 m to 1400 m in June and July 2001. Collection was carried out on June 8, June 23 and July 15

Species	Altitude (m)					Total
	1000	1100	1200	1300	1400	
Carabidae						
Carabus arrowianus nakamurai (Ishikawa)			1			1
Leptocarabus procerulus (Chaudoir)			2	63	3	68
Leptocarabus arboreus horioi (Nakane)				2	1	3
Pterostichus samurai (Lutshnik)		1				1
Pterostichus subovatus (Motschulsky)	1	1		45	33	79
Pterostichus yoritomus Bates	1					1
Pterostichus abaciformis Straneo				1		1
Pterostichus kosakai Morita				1		1
Pterostichus sp.1			1			1
Platynus subovatus (Putzeys)				3		3
Colpodes bentonis Bate				1		1
Colpodes (*Negreum*) sp.	1			2		3
Colpodes integratus Bates				1		1
Synuchus nitidus (Motschulsky)	1				1	2
Synuchus cycloderus (Bates)	2				1	3
Anisodactylus tricuspidatus Morawitz	2					2
Brachinidae						
Brachinus stenoderus Bates				1		1
Brachinus nigridorsis Nakane				4		4
Total	8	1	4	124	39	176
Number of traps in three times collections	19	21	21	21	21	103

Table 3 Species and numbers of ground beetles collected at 11 survey sites from 1000 m to 2600 m in August and Septemver 2001

Species	Altitude (m)											Total
	1000	1100	1200	1300	1400	1600	1800	2000	2200	2400	2600	
Carabidae												
Leptocarabus procerulus (Chaudoir)	3	3		20	6	1						33
Leptocarabus arboreus horioi (Nakane)					1	72	196	82	110	88	48	597
Damaster blaptoides oxuroides (Schaum)								2				2
Leistus subaeneus Bates									1	1		2
Leistus sp.								3	8	2	3	16
Broscosoma doenitzi (Harold)									1			1
Trigonognatha aurescens Bates					1	25	28	24	26	31	295	430
Pterostichus oblongopunctatus honshuensis Habu *et* Baba							13	3	41	2	1	60
Pterostichus subovatus (Motschulsky)				2	7							9
Pterostichus yoritomus Bates						1						1
Pterostichus fortis Morawitz		2										2
Pterostichus abaciformis Straneo	1											1
Pterostichus yatsuensis ishidai Tanaka						1		2		51	2	56
Pterostichus asymmetricus Bates						2						2
Pterostichus brunneipennis akaishicus Tanaka				2		19	50	90	89	75	78	403
Pterostichus kosakai Morita					2	11	1					14
Pterostichus masumotoi Tanaka, Morita *et* Suga				1		32	1					34
Pterostichus sp.2						1						1
Pterostichus sp.3 (*defossus* Bates ?)						1						1
Colpodes xestus (Bates)							30		5	18	29	82
Pristosia aeneola (Bates)							2	3	6	4	7	22
Synuchus nitidus (Motschulsky)	26		1	2		2						31
Synuchus cycloderus (Bates)	11		6	29	26	35	49	37	23	3		219
Synuchus melantho (Bates)	1		2	2	1	1						7
Synuchus congruus (Morawitz)	3		2		6							11
Synuchus sp.						22	7	1	1			31
Anisodactylus tricuspidatus Morawitz	1											1
Trichotichnus sp.							4		60	6	21	91
Brachinidae												
Brachinus stenoderus Bates				1								1
Total	46	5	11	59	50	50	381	247	371	281	484	2161
Number of traps in twice collections	9	11	9	9	11	7	8	8	10	10	8	94

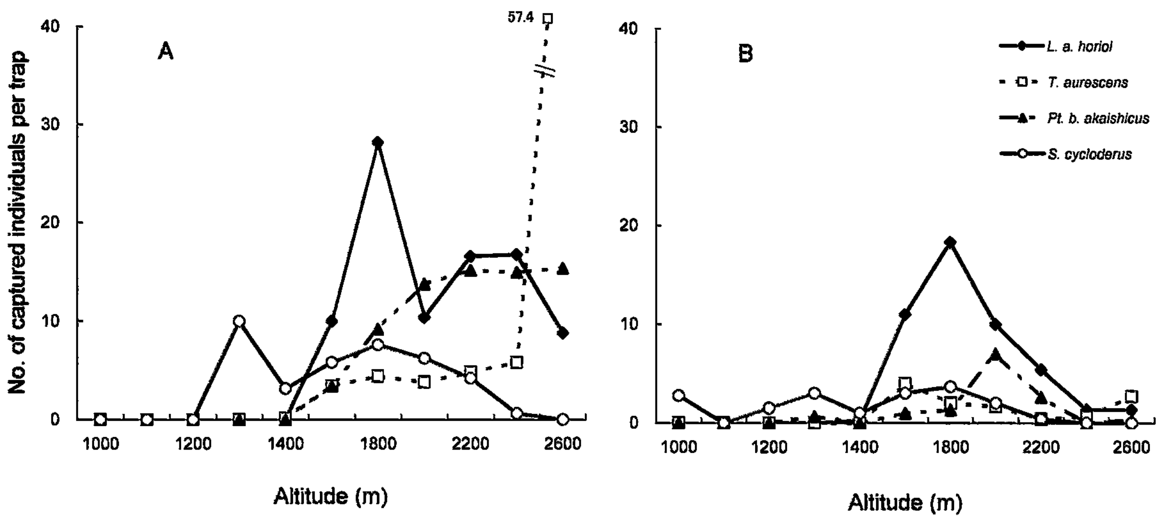

Fig. 2 Numbers of individuals of the 4 dominant species collected at different altitude from 1000 m to 2600 m in August (A) and September (B).

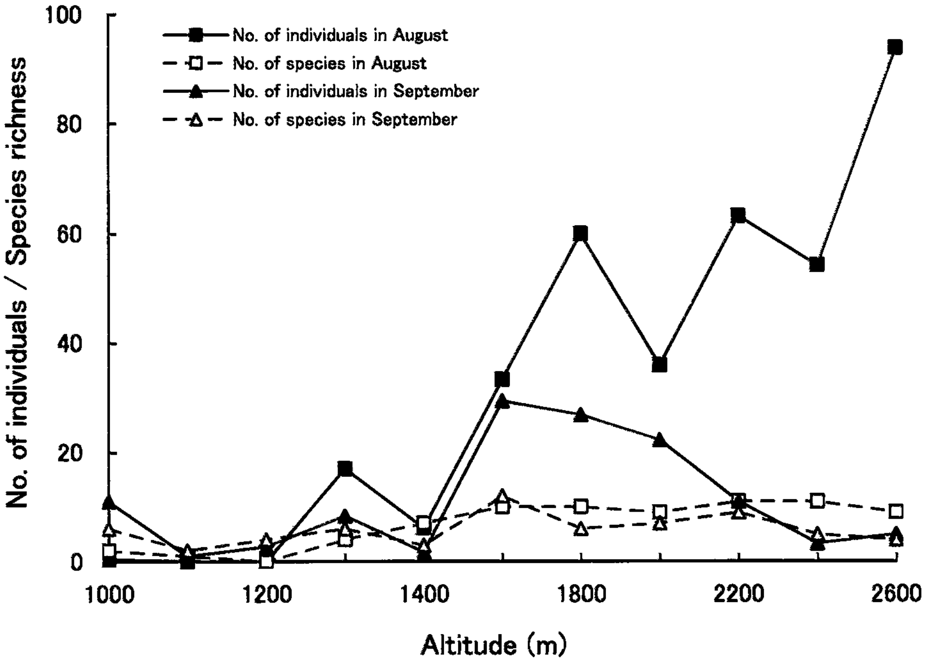

Fig. 3 Total numbers of individuals and species collected at altitudes from 1000 m to 2600 m in August and September.

species collected in August and September were almost the same at all survey sites.

Niche breadth

Figure 4 shows the niche breadth of ground beetles calculated using the data in **Table 3**, and the vertical range of survey sites at which ground beetles were captured in August and September. The 5 species which showed the high values of niche breadth were *S. cycloderus, Pt. brunneipennis akaishicus, L. arboreus horioi, P. aeneola* and *Synuchus melantho. S. cycloderus* showed a wide vertical distribution from 1000 m to 2400 m and also showed the highest value of niche breadth.

Figure 5 shows the relationship between niche breadth and relative abundance, which was calculated using the data in **Table 3.** The correlation coefficient (r) calculated for all species (n = 29) was 0.604 ($P < 0.01$), however, the 29 species shown in **Fig. 5** were divided into 3 groups: 4 species which had high values of both niche breadth and relative abundance, *S. cycloderus, Pt. brunneipennis akaishicus, T. aurescens* and *L. arboreus horioi*; 7 species which were represented by only 1 captured individual each **(Table 3)**; and the remaining 18 species. The correlation coefficient (r) calculated for the last group (n = 18) was 0.316 (P = 0.231), which indicated no relationship between niche breadth and relative abundance.

The mean altitude of species *i* can be calculated with the following formula using p_{ij}, which is the proportion of individuals collected at the *j*th study site in the total sample of the species *i*:

$$\text{Mean altitude} = \Sigma\,(\text{Altitude (m) of the } j\text{th site} \times p_{ij})$$

$$p_{ij} = n_{ij} / \Sigma\, n_{ij}$$

where nij is the number of trapped species i at the jth study site. This value indicates the mean height of the vertical distribution of species i. **Figure 6** shows the relationship between niche breadth and mean altitude. The correlation coefficient (r) calculated for all species (n = 29) was 0.393 (P = 0.03) indicating a slightly positive relationship. However, the correlation coefficient (r) calculated for the data excluding the 10 species whose niche breadths were zero (n = 19) was 0.200 (P = 0.843).

Discussion

Three hundred seven species of insects including 62 carabid species were designated as endangered species of Nagano Prefecture in 2004 (Nagano Nature Conservation Research Institute, 2004). In the present study, 1 vulnerable (VU) species and 5 nearer threatened (NT) species were captured. *Pt. kosakai* (VU) was recorded as a new species in 1998, at which time its distribution area was only around Mt. Senjo in the Southern Japanese Alps (Morita, 1998) . The distribution ranges of 4 NT species, *L. arboreus horioi,*

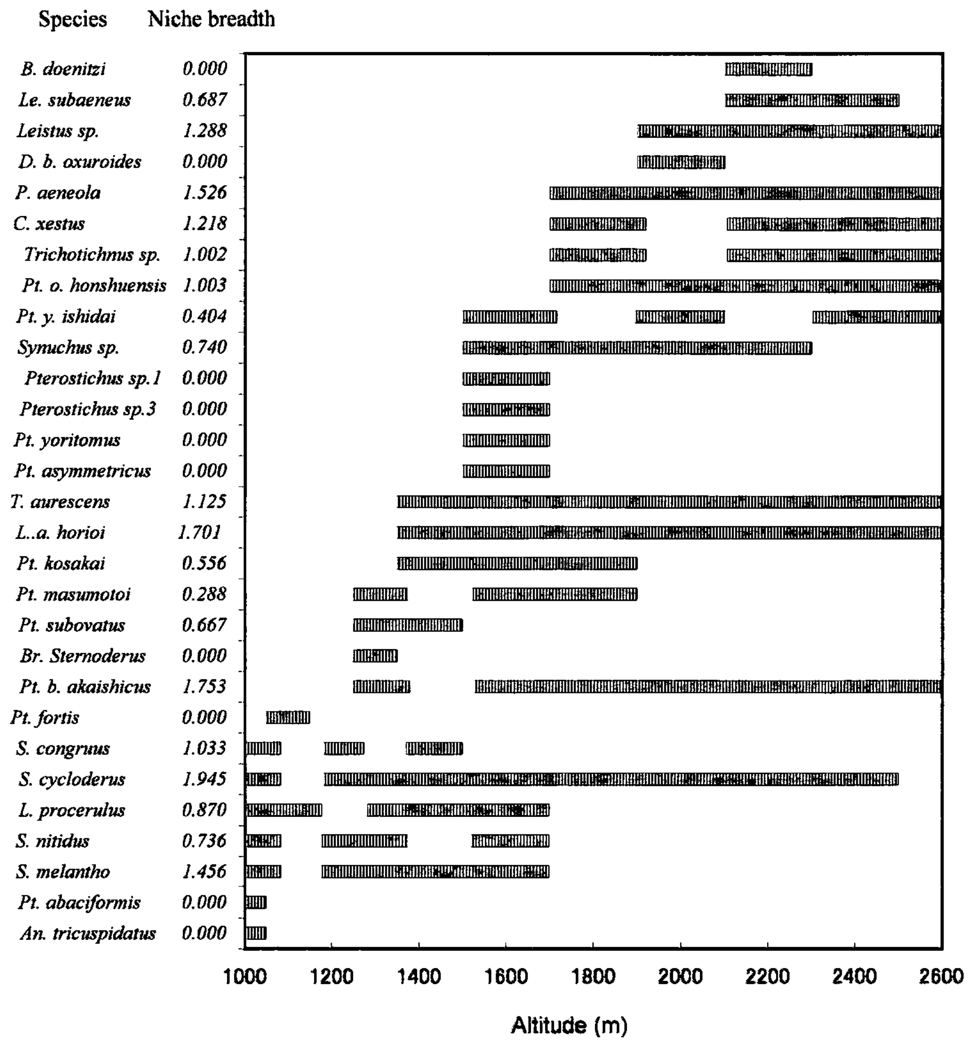

Fig. 4 Niche breadth of ground beetles and the vertical range of survey sites at which ground beetles were captured in August and September.

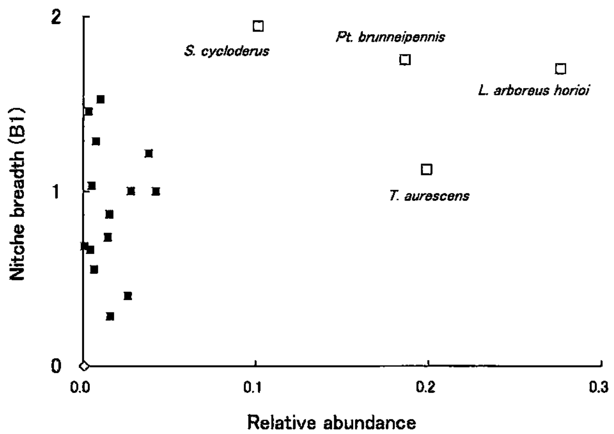

Fig. 5 Relationship between niche breadth and relative abundance. □: Four species which had high values of both niche breadth and relative abundance.◇: Seven species which were represented by only 1 captured individual each (see **Table 3**).

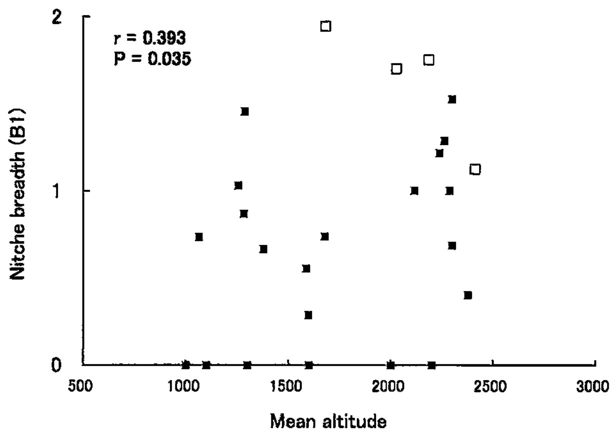

Fig. 6 Relationship between niche breadth and mean altitude. □: *S. cycloderus*, *Pt. brunneipennis akaishicus*, *T. aurescens* and *L. arboreus horioi*, which showed high values of both niche breadth and relative abundance.

Pt. yatsuensis ishidai, Pt. brunneipennis akaishicus and *Pt. masumotoi* were limited to a virgin forest of the subalpine zone in the Southern Japan Alps (Nagano Nature Conservation Research Institute, 2004). In the present study, *L. arboreus horioi* and *Pt. brunneipennis akaishicus* were dominant (**Table 3**) as they were 10 years ago (Martin, 1992). It is important for the preservation of endangered carabid beetles in the Southern Japan Alps that changes in their abundances be regularly monitored.

The number of species collected in the present study was fewer than those recorded by Martin (1992), possibly due to the short survey period and small survey area. However, several dominant species, *L. arboreus horioi, T. aurescens* and *Pt. brunneipennis akaishicus* (**Table 3**), were similar to those reported by Martin (1992). On the other hand, *Trichotichnus* sp. was found to be a dominant species in the present study, but the captured individuals of *Trichotichnus* species in Martin's survey (1992) were 2 or fewer. This suggests that there may be some species in high mountainous areas whose abundance changes abruptly.

S. cycloderus was the fourth dominant species in the present study, showing a wide vertical distribution from 1000 m to 2400 m and the highest value of niche breadth (**Fig. 4**), but ten years ago only 76 individuals were captured from 1000 m to 2200 m (Martin, 1992). Ishitani (1996) named ground beetles with wide habitation niche breadth as "species group which invades after disturbance" based on research on many different environments. Environmental disturbance in the present mountainous area was caused by the construction of the South Alps forest road. However, as *S. cycloderus* is a forest species, it can not be definitively stated that its increased vertical distribution was caused by the opening of the South Alps forest road. It may be that the wide niche breadth of this species indicates the results of its adaptation to the forest environment in the Southern Japan Alps, as in the case of *Pt. brunneipennis akaishicus*, which shows large nitche breadth in spite of its status as an endangered species.

Dominant species are generally known as euryecious species with wide niche breadth (Levins, 1968). However, Kobayashi (1995) reports that there are some cases in which species with narrow niche breadth show greater abundance and that there is no consistent relationship between niche breadth and relative abundance by analyzing Kamimuras' data (1962) of ground beetles at Mt. Jonen. In the present study, species of high relative abundance showed wide niche breadth, though we found no relationship between niche breadth and relative abundance among species of low abundance (**Fig. 5**). These results indicate that it is reasonable to identify the dominant speices with wide vertical niche breadth as an euryecious carabid beetle in the subalpine forest of the Southern Japan Alps.

In an attempt to assess the environment of a mountainous area using ground beetles as an environmental indicator, a number of species were taken into consideration. The 3 dominant species, *L. arboreus horioi, T. aurescens* and *Pt. brunneipennis akaishicus* were identified as the representative ground beetles of the coniferous forest from 1500 m to 2600 m in the Southern Japan Alps. *Pterostichus abaciformis, Anisodactylus tricuspidatus, Pterostichus fortis, Brachinus sternoderus* and *Pt. subovatus* were found primarily at altitudes from 1000 m to 1400 m, and were either not found or were found only in very small numbers at other sites (**Fig. 4**). As the captured number of *Pt. subovatus* was the highest of these 5 species (**Tables 2 and 3**), this species may be the most typical in this altitude range. Kamimura *et al.* (1962) also report that *Pt. subovatus* was dominant in the range from 1100 m to 1600 m at Mt. Jonen. Above 1800 m, *Pt. oblongopunctatus honshuensis, C. xestus and Pr. aeneola* were deemed typical because of their high relative abundance and easy identification.

Martin (1987) reports that the *Pterostichus* species are appropriate indicators of environmental disturbance at all altitudes in the Southern Japan Alps. The results of the present study indicate that these *Pterostichus* species are important bioindicators of the subalpine forest in the Southern Japan Alps. Nevertheless, further study should be carried out to confirm these findings.

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南アルプスにおける地上性甲虫（オサムシ科，クビボソゴミムシ科）の群集構造と標高のニッチ幅

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南アルプスにおける地上性甲虫類の群集構造と標高に対するニッチ幅をあきらかにするため，2001 年 6 月から 9 月にかけて調査を行った．仙丈ヶ岳周辺の標高 1000 m から 2600 m の範囲に，11 の調査地点を設けた．乳酸飲料と 70% エチルアルコールを入れたトラップによる採集は，2001 年 6 月には標高 1000 m から 1400 m の 7 調査地点で 3 回，7 月から 9 月には標高 1000 m から 2600 m の範囲で 2 回行われた．本調査で合計 37 種 2337 個体のオサムシ科とクビボソゴミムシ科の地上性昆虫が採集された．6 月の調査での優占種は，マルガタナガゴミムシ *Pterostichus subovatus*（全体の 44.9%）とクロナガオサムシ *Leptocarabus procerulus*（全体の 38.6%）であった．8 月と 9 月の調査での優占種は，サンプククロナガオサムシ *Leptocarabus arboreus horioi*, キンイロオオゴミムシ *Trigonognatha aurescens*, ハネアカナガゴミムシ *Pterostichus brunneipennis akaishicus* およびクロツヤヒラタゴミムシ *Synuchus cycloderus* で，これら 4 種で 1649 個体，全体の 76.3% を占めていた．8 月と 9 月の調査結果をもとに標高に対するニッチ幅が計算され，クロツヤヒラタゴミムシ，ハネアカナガゴミムシ，サンプククロナガオサムシ，ホソヒラタゴミムシ *Pristosia aeneola* およびコクロツヤヒラタゴミムシ *Synuchus melantho* が高い値を示した．特にクロツヤヒラタゴミムシは，標高 1000 m から 2400 m までの広い垂直分布を示した．捕獲個体数の多い種は，広いニッチ幅を持っていた．ただし，個体数の少ない種では，ニッチ幅と捕獲数の相関はみられなかった．ニッチ幅と分布域の平均標高との間には，弱い正の相関が見られた．これらの結果から，山岳環境を代表する指標種について考察した．