

Far Eastern Entomologist

Дальневосточный энтомолог

Journal published by Far East Branch
of the Russian Entomological Society
and Laboratory of Entomology,
Institute of Biology and Soil Science,
Vladivostok

Number 287: 1-23

ISSN 1026-051X

January 2015

[hppt/ urn:lsid:zoobank.org:pub: 882256C7-5C3E-4EB5-A0A1-494A917D2417](http://urn:lsid:zoobank.org:pub:882256C7-5C3E-4EB5-A0A1-494A917D2417)

COMPARISON OF ABUNDANCE AND DIVERSITY OF BEES (HYMENOPTERA: APOIDEA) COLLECTED BY WINDOW TRAPS AMONG FOUR TYPES OF FOREST ON NOTO PENINSULA, JAPAN

**W. Priawandiputra¹⁾, C. Y. Barsulo²⁾, A. D. Permana³⁾,
K. Nakamura²⁾**

1) *Graduate School of Natural Science and Technology, Kanazawa University, Kakuma, Kanazawa 920-1192, Japan, E-mail: priawandiputra_windra@yahoo.co.id*

2) *The Satoyama Satoumi Project, Kanazawa University, Kanazawa 920-1192, Japan, E-mail: chriswebyan@gmail.com and kojink@staff.kanazawa-u.ac.jp*

3) *School of Life Science and Technology, Bandung Institute of Technology, Bandung, Indonesia, E-mail: agus@sith.itb.ac.id*

A total of 426 individuals in 25 species and 5 families of bees were collected monthly from May to October in 2009 and 2010 using window traps at canopy and ground levels from four types of forest (pine, deciduous, evergreen and sugi) on Noto Peninsula. The highest numbers of individuals and species were recorded in pine forests, where no significant difference was found between managed and unmanaged sites. The abundance and diversity of bees were generally higher at canopy than at ground level.

KEY WORDS: bee assemblage, pine forest, window trap, forest management.

В. Вриавандипутра¹⁾, Х. Я. Барсуло²⁾, А. Д. Пермана³⁾, К. Накамура²⁾.
Сравнение численности и разнообразия пчёл (Hymenoptera: Apoidea), собранных оконными ловушками в четырех типах лесов на полуострове Ното (Япония) // Дальневосточный энтомолог. 2015. N 287. С. 1-23.

На полуострове Ното в четырех типах лесов (сосняках, листопадных и вечнозеленых лесах и посадках криптомерии) в 2009-2010 гг. собрано 426 экз. пчёл, относящихся к 25 видам из 5 семейств. Сборы производились ежемесячно с мая по октябрь с использованием оконных ловушек, установленных в кронах деревьев и на уровне почвы. Наибольшее число экземпляров и видов отмечено в сосновых лесах, причем существенных различий между естественными и подверженными хозяйственной деятельности участками не выявлено. Численность и видовое разнообразие пчёл в кронах деревьев в целом оказалось выше, чем на уровне почвы.

1) Школа естественных наук и технологий, университет Канадзава, Япония.

2) Университет Канадзава, Япония.

3) Школа естественных наук и технологий, университет Бандунга, Индонезия.

INTRODUCTION

Satoyama is a dynamic mosaic of socio-ecological production landscapes, covering 40 and 60% of Japan's national land and Ishikawa Prefecture, respectively (JSSA, 2010). It is important because it produces a range of ecosystem services for human wellbeing, for which biodiversity is a key element (Washitani, 2001; Kobori & Primack, 2003). In Japan, the human population is decreasing and aging, resulting in an increase of abandoned satoyama areas, which in turn causes the deterioration of biodiversity and the decrease of ecosystem services from satoyama (JSSA, 2010; The National Biodiversity Strategy of Japan 2012-2020). For example, on Noto Peninsula, the production of matsutake mushrooms (*Tricholoma matsutake*) has decreased markedly due to an increase of abandoned pine forests (Linawati *et al.*, 2006).

In our preceding studies, we quantitatively investigated the changes in invertebrate biodiversity in the forests of Noto Peninsula. First, Linawati *et al.* (2006) reported the effects of red-pine (*Pinus densiflora*) forest management for the revival of matsutake mushroom production on invertebrate communities using four sampling methods, namely, window and pitfall traps, and the sampling of litter and soil. Second, Barsulo (2011) compared the flying insect assemblages as an indicator of forest conditions among four types of forest, namely, red-pine (*Pinus densiflora*) forest, deciduous (*Quercus*) forest, evergreen forest predominated by *Quercus*, *Machilus thunbergii* and *Camellia japonica*, and a plantation of sugi (*Cryptomeria japonica*). The samples were collected using IBOY window traps at canopy and ground levels. He showed that beetle assemblages differed among forest types. In pine forests, the beetle assemblages differed between canopy and ground levels, but not between managed and unmanaged forests (Barsulo & Nakamura, 2011).

In the present study, we used bees as an indicator of forest conditions. The bee samples were sorted from the samples collected by Barsulo (2011). Bees, which are influenced by the proximity to forest, are crucial pollinators in wild habitats and agricultural ecosystems (Michener, 2000; James & Pitts-Singer, 2008; Brosi *et al.*,

2007). We aimed to compare the species composition and abundance of bees: (1) among different forest types, (2) between canopy and ground levels, (3) between different types of management (especially in red-pine forests), (4) with those of beetles collected in the same sample (Basulo, 2011; Barsulo & Nakamura, 2011) and (5) with those of bees collected from non-forested habitats in satoyama using sweeping nets on Noto Peninsula (Kasagi *et al.*, 2012) and in Kanazawa, located 100 km southwest of the present study area (Putra, 2009; Priawandiputra and Nakamura, unpublished data).

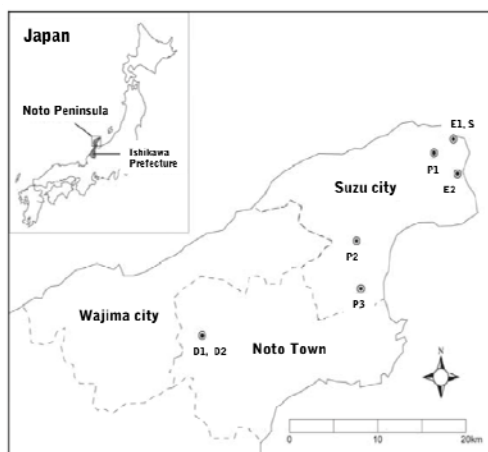


Fig. 1. Map of the study sites at the tip of Noto Peninsula (Ishikawa, Japan): P = pine forest, D = deciduous forest, E = evergreen forest and S = sugi forest.



Fig. 2. IBOY-type window trap set at canopy and ground levels.

STUDY SITES

This study was conducted in Suzu City and Noto Town, located on the north of Noto Peninsula, Ishikawa, Japan (Fig. 1), as mentioned in previous articles (Barsulo & Nakamura, 2011; Barsulo, 2011).

SAMPLING METHODS

Window traps. Flying insects including beetles and bees were collected monthly 12 times in total from May-October 2009 (6 times) and May-October 2010 (6 times), using the IBOY standard window traps (Nakashizuka & Stork, 2002; Kearns & Inouye, 1993), which consisted of a yellow collecting bucket (diameter 35 cm and 15 cm high) and 2 transparent intersect panels (50 cm high x 45 cm wide) (Fig. 2). The traps were placed in 11 study sites, including 6 pine, 2 deciduous, 2 evergreen and 1 sugi sites (for details, see Table 1). The pine sites included 3 pairs of managed

and 3 unmanaged sites, where the distance between a pair of managed and unmanaged sites was 10 to 20 m. In each sampling site, two replications, each containing two traps at ground (1.5 m from the ground) and canopy levels (10-15 m from the ground), were placed 10-20 m apart.

Identification of specimens. Bees were sorted from the samples collected from the studied sites. All collected bee specimens were pinned and 90% and 10% of them were identified to the species or genus level, respectively, using the reports by Michener (2000) and Yamane *et al.* (1999). The bee specimens were also compared with already identified museum specimens kept at Kanazawa University for further confirmation. Voucher specimens were deposited at the Laboratory of Ecology, Graduate School of Natural Science and Technology, Kanazawa University.

DATA ANALYSIS

Independence of sites. Before analysis, Mantel tests based on Monte-Carlo permutation were used to check the spatial autocorrelation of abundance and species richness of bees among the sites, using R, version 2.13.1, Ade4 package (R Development Core Team 2008; <http://www.R-project.org>).

Rarefaction of species estimators. Species accumulation curves (cumulative number of species collected against a measure of the sampling effort) were drawn for the bee data set in each forest type (pine, evergreen, deciduous and sugi) to estimate the number of unobserved species and then the sampling efficiency of the bees. Jackknife1 estimators were calculated using R, version 2.13.1, Vegan package (*ibid.*).

Comparison of abundance and species richness. Wilcoxon test and Kruskal-Wallis test (JMP version 5.0.1, SAS Institute) were used to examine the differences in abundance and species richness of bee assemblages among forest types, between strata (canopy and ground) and between types of management (managed and unmanaged) of pine forests.

Similarity. The degree of similarity of bee assemblages among forest types was analyzed by analysis of similarity (ANOSIM) using a Bray-Curtis matrix with 1000 permutations and non-metric multidimensional scaling (NMDS) based on Bray-Curtis. All analyses were performed using PAST software version 1.95 (Hammer *et al.*, 2001).

RESULTS

1. Independence of sites

The results of the Mantel test (9999 replicates) indicated no significant correlation, first, between the location of sampling sites and bee abundance, and second, between the location of sampling sites and number of bee species, which showed statistical independence of the sampling sites in this study ($r=-0.08$, $p=0.6$ and $r=-0.11$, $p=0.6$).

Table 1. Details of characteristics of the sampling sites mentioned in Barsulo & Nakamura (2011)

Forest types	Management	Replication	Location	Altitude (m)	Slope (degree)	Tree species found at the sampling site surrounding the traps
Pine	Managed	1	37°29'58.50"N, 137°18'22.60"E	129	0-30	<i>Pinus densiflora</i> , <i>Eurya japonica</i>
		2	37°25'26.30"N, 137°12'19.90"E	226	0-15	Ditto.
		3	37°22'52.20"N, 137°12'38.30"E	158	0-45	Ditto.
	Unmanaged	1	37°29'58.50"N, 137°18'22.60"E	129	0-30	<i>P. densiflora</i> , <i>Acer sieboldianum</i> , <i>Eleutherococcus sciadophylloides</i>
		2	37°25'26.30"N, 137°12'19.90"E	226	0-30	<i>P. densiflora</i> , <i>Quercus serrata</i> , <i>E. japonica</i> , <i>Ilex macropoda</i>
		3	37°22'52.20"N, 137°12'38.30"E	158	0-10	<i>P. densiflora</i> , <i>Q. serrata</i> , <i>A. sieboldianum</i> , <i>E. japonica</i> , <i>Cryptomeria japonica</i>
Deciduous	Managed	1	37°20'4.70"N, 137°0'48.10"E	277	0-10	<i>Q. serrata</i> , <i>Q. variabilis</i> , <i>A. sieboldianum</i> , <i>A. rufinerve</i> , <i>Carpinus japonica</i> , <i>Padus grayana</i>
		2	37°20'4.70"N, 137°0'48.10"E	277	0-30	Ditto.
Evergreen	Natural	1	37°30'38.40"N, 137°19'53.90"E	172	15-50	<i>Q. acuta</i> , <i>Machilus thunbergii</i> , <i>Camellia japonica</i> , <i>E. japonica</i> , <i>A. sieboldianum</i> , <i>Neoritsea sericea</i>
		2	37°28'47.80"N, 137°20'10.60"E	20	0-45	<i>Castanopsis sieboldii</i> , <i>C. japonica</i> , <i>M. thunbergii</i> , (<i>Sasa</i> sp., <i>Polystichum ohmurae</i>)
Sugi	Unmanaged	1	37°30'40.50"N, 137°19'56.90"E	167	0-30	<i>Cryptomeria japonica</i>

2. Estimating species richness

Figure 3 shows the species accumulation curves of the bees collected in each forest type and all forests combined. In pine forest, the accumulated number of species increased steeply from 6 species (1st sample) to 23 (7th), and then slowly approached an asymptote from 23 species (8th) to 25 (12th). Meanwhile, the trends in the other three forest types (deciduous, evergreen and sugi) differed from those for the pine forests, namely, the accumulated number of species did not rapidly increase during early samples, and then the asymptote was lower than that of pine

forests, namely, at 12, 9 and 4 species in deciduous, evergreen and sugi forests, respectively. The trend of accumulation curves for all forest types combined reflected that of pine forests.

Table 2 shows the number of species observed (a), that of species estimated by Jackknife1 (b) and the sampling ratio (c) for each forest type. The number of species observed for all forests combined and that for pine forests were the same (25 species), followed by deciduous (12), evergreen (9) and sugi forests (4). The Jackknife1 estimates were 31.4 (all forests combined), 32.3 (pine forests), 18.4 (deciduous forests), 12.7 (evergreen forests) and 5.8 (sugi forests). Sampling ratios, calculated as $a/b \times 100$, were 79.6, 77.3, 65.2, 70.8 and 68.9 for these categories. In pine forests, the sampling ratios in managed and unmanaged types were 71 and 75.7, respectively. As indicated above, the sampling ratio was sufficiently high to deal with the bee assemblages in this study.

Table 2. Comparison of the number of species observed and that estimated by Jackknife1 among forest types

Forest types	Deciduous	Evergreen	Pine			Sugi	All Forest
			Managed	Unmanaged	Managed + Unmanaged		
a. No. of species observed	12	9	20	20	25	4	25
b. Jackknife1 (SE)	18.4 (3.0)	12.7 (2.3)	28.2 (5.0)	26.4 (3.6)	32.3 (3.7)	5.8 (1.3)	31.4 (3.0)
c. Sampling ratio ($a/b \times 100$, %)	65.2	70.8	71	75.5	77.3	68.9	79.6

3. Abundance

3.1. All forests

A total of 426 bee individuals (9.7 individuals per trap) were collected from all forests (Table 6). No difference was found between the mean numbers of individuals collected at canopy (11.7 individuals per trap) and ground levels (7.6) (Wilcoxon test, $P > 0.05$).

3.2. Each forest type

Pine forest. Almost 70% of individuals of all samples were collected from pine forests (297 individuals and 12.4 individuals/trap) (Table 4, 5). In pine forests, the number of bees collected at canopy level (172 and 14.3) was larger than at ground level (125 and 10.4). The number of bees collected from managed pine forests (155 and 12.9) was higher than that from unmanaged ones (142 and 11.8), but no significant difference was found between managed and unmanaged pine forests in terms of whether or not the two levels of ground and canopy were combined (Wilcoxon and Kruskal-Wallis test, $P > 0.05$) (Fig. 4).

Other forests. The numbers of bees collected per trap in other forest types were smaller than in pine forest, namely, 11.2 at canopy and 5.5 at ground levels in deciduous forests, 8.7 and 5 in evergreen, and 2 and 0 in sugi (Table 3, 6).

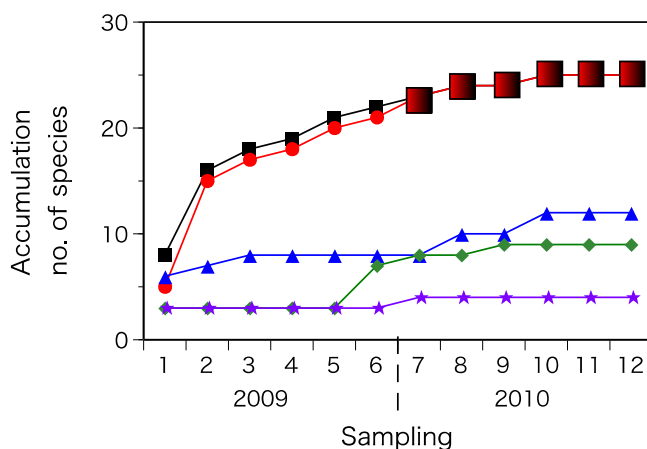


Fig. 3. The species accumulation curve for bees collected in each sample. Different symbols refer to different types of forest (all forests, ■; pine, ●; deciduous, ▲; evergreen, ◆; sugi, ★).

4. Family richness

4.1. All forests

From both ground and canopy levels combined for all forests, a total of 5 families, including Halictidae, Apidae, Andrenidae, Colletidae and Megachilidae, were recorded (Table 6). Three families (Halictidae, Apidae and Andrenidae) were collected at both canopy and ground levels. On the other hand, Colletidae was collected only at canopy level, while Megachilidae was collected only at ground level.

4.2. Each forest type

Pine forest: All families were found in pine forest, where Megachilidae was collected only at ground level in managed pine forest and Colletidae was collected only at canopy level in the unmanaged type (Table 4, 5).

Other forests: In deciduous and evergreen forests, only three families (Halictidae, Andrenidae and Apidae) were collected (Table 3). Meanwhile, in sugi forests, Andrenidae was collected at neither ground nor canopy level, and the other two families (Apidae and Halictidae) were found only at canopy level (Table 6 and Fig. 5).

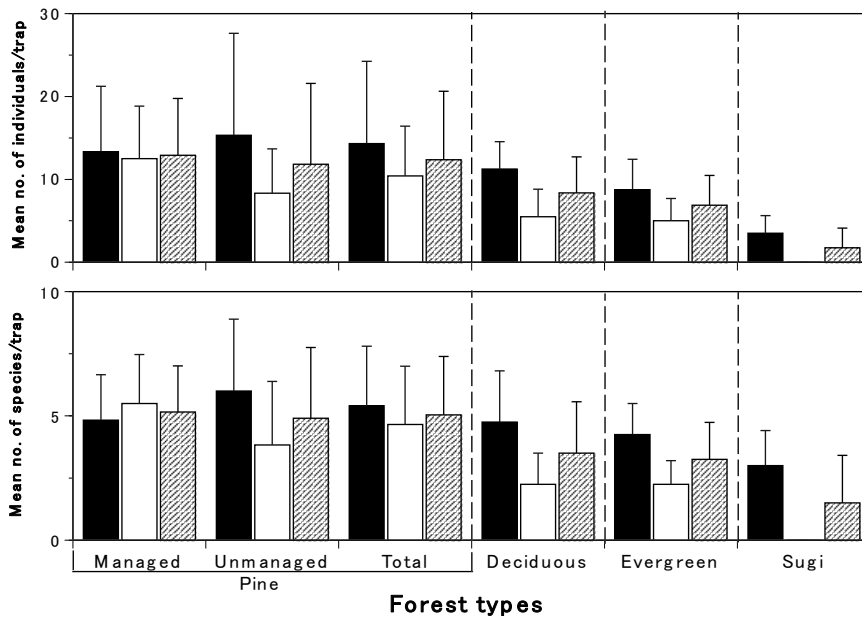


Fig. 4. Comparison of mean numbers of bee individuals (top) and species (bottom) collected per trap at canopy (■), ground (□) and both levels combined (▨) among the 4 forest types. For pine forests, data for managed and unmanaged forests are shown separately. Mean (column) \pm SD (error bar) are given.

5. Abundance at family level

5.1 All forests

In all forest data combined, the abundance ranking of the top five families was as follows: Apidae (306 individuals), Halictidae (85), Andrenidae (33), Colletidae (1) and Megachilidae (1) (Table 6). The same pattern was also shown in the other forests. Apidae was the top-ranked family in terms of abundance at both canopy (190 individuals) and ground levels (116) among the families.

5.2 Each forest type

Pine forest. In pine forests, Apidae was the most abundant family (209 individuals) and was more abundant at canopy than at ground level (129 individuals at canopy and 80 at ground level) (Table 4, 5). The abundances of Apidae (106 in managed and 103 in unmanaged types) and Halictidae (34 in managed and 33 in unmanaged types) were significantly greater than those of other families in both managed and unmanaged forest types (Kruskal-Wallis test, $P < 0.0001$) (Fig. 5). No significant difference was found in abundance between managed and unmanaged types for all families (Kruskal-Wallis test, $P > 0.05$) (Fig. 5).

Table 3. List of the bees collected from the deciduous and evergreen forest

Family	Species	Bee code	Deciduous (2)			Evergreen (2)		
			C(4)	G(4)	T(8)	C(4)	G(4)	T(8)
Andrenidae	<i>Andrena japonica</i> Cockerell	3	0.25 (1)	0.25 (1)	0.25 (2)	0.25 (1)	0 (0)	0.12 (1)
	<i>A. kaguya</i> Hirashima	6	2.25 (9)	0.5 (2)	1.38 (11)	0 (0)	0 (0)	0 (0)
	Number of individuals	-	2.5 (10)	0.75 (3)	0.16 (13)	0.25 (1)	0 (0)	0.12 (1)
	Number of species	-	0.5 (2)	0.5 (2)	0.25 (2)	0.25 (1)	0 (0)	0.25 (1)
Apidae	<i>Bombus ardens</i> <i>ardens</i> Smith	5	0.25 (1)	0 (0)	0.12 (1)	1.25 (5)	0.25 (1)	0.75 (6)
	<i>B. diversus diversus</i> Smith	1	4.25 (17)	4.25 (17)	4.25 (34)	3.5 (14)	3.5 (14)	3.5 (28)
	<i>B. hypocrita</i> <i>hypocrita</i> Perez	7	1.5 (6)	0 (0)	0.75 (6)	0 (0)	0.25 (1)	0.12 (1)
	<i>B. ignitus</i> Smith	2	0.5 (2)	0.5 (2)	0.5 (4)	2.25 (9)	0.25 (1)	1.25 (10)
	<i>Ceratina japonica</i> Cockerell	11	0.25 (1)	0 (0)	0.12 (1)	0 (0)	0 (0)	0 (0)
	<i>Tetralonia mitsukurii</i> Cockerell	24	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	<i>Xylocopa</i> <i>appendiculata</i> <i>circumvolans</i> Smith	25	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Number of individuals	-	6.75 (27)	4.75 (19)	5.75 (46)	7 (28)	4.25 (17)	5.62 (45)
	Number of species	-	1.25 (5)	0.5 (2)	0.62 (5)	0.75 (3)	1 (4)	0.5 (4)
Halictidae	<i>Lasioglossum</i> <i>amamiense</i> Ebmer et Sakagami	14	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	<i>L. japonicum</i> Dalla torre	4	1 (4)	0 (0)	0.5 (4)	0.75 (3)	0.25 (1)	0.5 (4)
	<i>L. kuroshio</i> Sakagami et Takahashi	8	0.25 (1)	0 (0)	0.12 (1)	0 (0)	0.5 (2)	0.25 (2)
	<i>L. mutilum</i> Vachal	15	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	<i>L. nipponicola</i> Sakagami et Tadauchi	16	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	<i>L. occidens</i> Smith	17	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	<i>L. ohei</i> Hirashima et Sakagami	18	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	<i>L. primavera</i> Sakagami et Maeta	19	0.25 (1)	0 (0)	0.12 (1)	0 (0)	0 (0)	0 (0)
	<i>L. proximatum</i> Smith	9	0.25 (1)	0 (0)	0.12 (1)	0.5 (2)	0 (0)	0.25 (2)
	<i>L. sibiriacum</i> Bluthgen	20	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	<i>Lasioglossum</i> sp.	21	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table 3 (continued)

Family	Species	Bee code	Deciduous (2)			Evergreen (2)		
			C(4)	G(4)	T(8)	C(4)	G(4)	T(8)
Halictidae	<i>L. villosulum trichopse</i> Strand	22	0.25 (1)	0 (0)	0.12 (1)	0.25 (1)	0 (0)	0.12 (1)
	<i>L. vulsum</i> Vachal	10	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	<i>Sphecodes</i> sp.	23	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Number of individuals	-	2 (8)	0 (0)	1 (8)	1.5 (6)	0.75 (3)	1.1 (9)
	Number of species	-	1.25 (5)	0 (0)	0.62 (5)	0.75 (3)	0.5 (2)	0.5 (4)
Colletidae	<i>Hylaeus floralis</i> Smith	13	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Megachilidae	<i>Coelioxys yanonis</i> Matsumura	12	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Total no. of individuals			11.2 (45)	5.5 (22)	8.4 (67)	8.7 (35)	5 (20)	6.9 (55)
Total no. of species			4.7 (12)	2.2 (4)	3.5 (12)	4.2 (7)	2.2 (5)	3.2 (9)

Abbreviations. Numbers in parentheses in each forest indicate numbers of sites. Strata: C = canopy, G = ground, T = C+G. Numbers in parentheses beside C, G and T refer to number of traps. Number for each bee species refers to number of individuals collected per trap and that in parentheses is total number collected at C, G and T in each site.

Other forest. The abundance of these families in other forests was lower than that in pine forest, namely, Apidae (46 in deciduous, 45 in evergreen and 6 in sugi), Halictidae (67, 9 and 1) and Andrenidae (13, 1 and 0) (Table 3, 6). Apidae was more abundant at canopy than at ground level, namely, deciduous (27 vs. 19), evergreen (28 vs. 17) and sugi (6 vs. 0). Apidae was significantly more abundant than other families at both layers in all forest types (Fig. 5, Kruskal-Wallis test, $P < 0.05$).

6. Species richness

6.1. All forests

A total of 25 species were collected from all forest types, including Halictidae (14 species), Apidae (7), Andrenidae (2), Collectidae (1) and Megachilidae (1) (Table 6). Halictidae had the highest number of species in both strata (13 and 13 species at canopy and ground levels, respectively), compared with Apidae (5 and 7), Andrenidae (2 and 2), Colletidae (1 and 0) and Megachilidae (0 and 1). The same pattern was also shown in other forests. The number of species per trap at canopy level (4.8 species per trap) was significantly higher than at ground level (3.3) (Wilcoxon test, $P = 0.02$), although the number of species at canopy level (21 species) was lower than at ground level (23).

6.2. Each forest type

Pine forest. The largest number of species was found in pine forests (25 species and 5 species per trap) (Table 4, 5 and Fig. 4). The numbers of species in Halictidae

Table 4. List of the bees collected from the pine forest

Family	Species	Bee code	Managed (3)			Unmanaged (3)		
			C(6)	G(6)		C(6)	G(6)	
Andrenidae	<i>Andrena japonica</i>	3	0.5 (3)	0.16 (1)	0.33 (4)	0.16 (1)	0.16 (1)	0.16 (2)
	<i>A. kaguya</i>	6	0.83 (5)	1.66 (5)	0.83 (10)	0 (0)	0.5 (3)	0.25 (3)
	Number of individuals	-	1.3 (8)	1 (6)	1.1 (14)	0.16 (1)	0.6 (4)	0.41 (5)
	Number of species	-	0.3 (2)	0.3 (2)	0.16 (2)	0.16 (1)	0.3 (2)	0.16 (2)
Apidae	<i>Bombus ardens ardens</i>	5	0.66 (4)	0 (0)	0.33 (4)	0.5 (3)	0.16 (1)	0.33 (4)
	<i>B. diversus diversus</i>	1	7.5 (45)	13.33 (40)	7.08 (85)	8.16 (49)	4.66 (28)	6.41 (77)
	<i>B. hypocrita hypocrita</i>	7	0.5 (3)	0.16 (1)	0.33 (4)	1 (6)	0.33 (2)	0.66 (8)
	<i>B. ignitus</i>	2	1.16 (7)	0.33 (2)	0.75 (9)	1.16 (7)	0.33 (2)	0.75 (9)
	<i>Ceratina japonica</i>	11	0.16 (1)	0.16 (1)	0.16 (2)	0.66 (4)	0.16 (1)	0.41 (5)
	<i>Tetralonia mitsukurii</i>	24	0 (0)	0.16 (1)	0.08 (1)	0 (0)	0 (0)	0 (0)
	<i>Xylocopa appendiculata circumvolans</i>	25	0 (0)	0.16 (1)	0.08 (1)	0 (0)	0 (0)	0 (0)
	Number of individuals	-	10 (60)	7.6 (46)	8.83 (106)	11.5 (69)	5.67 (34)	8.58 (103)
	Number of species	-	0.83 (5)	1 (6)	0.58 (7)	0.83 (5)	0.83 (5)	0.41 (5)
Halictidae	<i>Lasioglossum amamiense</i>	14	0 (0)	0.16 (1)	0.08 (1)	0.16 (1)	0 (0)	0.08 (1)
	<i>L. japonicum</i>	4	0.83 (5)	1.33 (4)	0.75 (9)	1 (6)	1 (6)	1 (12)
	<i>L. kuroshio</i>	8	0.5 (3)	3 (9)	1 (12)	0.33 (2)	0 (0)	0.16 (2)
	<i>L. mutilum</i> Vachal	15	0 (0)	0.16 (1)	0.08 (1)	0 (0)	0.16 (1)	0.08 (1)
	<i>L. nipponicola</i>	16	0 (0)	0 (0)	0 (0)	0.16 (1)	0.16 (1)	0.16 (2)
	<i>L. occidens</i>	17	0 (0)	0.16 (1)	0.08 (1)	0.33 (2)	0 (0)	0.16 (2)
	<i>L. ohei</i>	18	0 (0)	0.16 (1)	0.08 (1)	0 (0)	0 (0)	0 (0)
	<i>L. primavera</i>	19	0 (0)	0.16 (1)	0.08 (1)	0 (0)	0 (0)	0 (0)
	<i>L. proximatium</i>	9	0.33 (2)	0.33 (2)	0.33 (4)	0.33 (2)	0.16 (1)	0.25 (3)
	<i>L. sibiriacum</i>	20	0 (0)	0.16 (1)	0.08 (1)	0.5 (3)	0.16 (1)	0.33 (4)
	<i>Lasioglossum</i> sp.	21	0 (0)	0 (0)	0 (0)	0.16 (1)	0.16 (1)	0.16 (2)

Table 4 (continued)

Family	Species	Bee code	Managed (3)			Unmanaged (3)		
			C(6)	G(6)		C(6)	G(6)	
Halictidae	<i>L. villosulum trichopse</i>	22	0 (0)	0 (0)	0 (0)	0 (0)	0.16 (1)	0.08 (1)
	<i>L. vulsum</i>	10	0.33 (2)	0.16 (1)	0.25 (3)	0.33 (2)	0 (0)	0.67 (2)
	<i>Sphecodes</i> sp.	23	0 (0)	0 (0)	0 (0)	0.16 (1)	0 (0)	0.16 (2)
	Number of individuals	-	2 (12)	3.67 (22)	2.83 (34)	3.5 (21)	2 (12)	2.75 (33)
	Number of species	-	0.66 (4)	1.66 (10)	0.83 (10)	1.66 (10)	1.16 (7)	1 (12)
Colletidae	<i>Hylaeus floralis</i>	13	0 (0)	0 (0)	0 (0)	0.16 (1)	0 (0)	0.16 (2)
Megachilidae	<i>Coelioxys yanonis</i>	12	0 (0)	0.16 (1)	0.08 (1)	0 (0)	0 (0)	0 (0)
Total no. of individuals			11.2 (45)	5.5 (22)	13.3 (80)	12.5 (75)	12.9 (155)	15.3 (92)
Total no. of species			4.7 (12)	2.2 (4)	4.8 (11)	5.5 (19)	5.1 (20)	6 (17)

Abbreviations see Table 3.

(14 species and 2.1 species per trap) and Apidae (7 and 2.2) were significantly higher than those in Andrenidae (2 and 0.5), Colletidae (1 and 0.04) and Megachilidae (1 and 0.04) (Kruskal-Wallis test, $P < 0.0001$) (Fig. 5). The number of species was not significantly different between canopy (18 and 5.4) and ground levels (23 and 4.6) (Wilcoxon test, $P > 0.05$) (Fig. 4). The number of species per trap for each family also did not differ significantly between canopy and ground levels (Wilcoxon test, $P > 0.05$) (Fig. 5). The numbers of species in Halictidae (10 species in managed and 12 species in unmanaged types) and Apidae (7 and 5) were larger than in other families. In each family, no significant difference was found either between the two levels of canopy and ground or between managed and unmanaged types (Kruskal-Wallis test, $P > 0.05$) (Fig. 5). The numbers of species in Apidae and Halictidae at both layers in managed and unmanaged pine forests were significantly higher than those in other families (Kruskal-Wallis test, $P < 0.0001$) (Fig. 5). The total numbers of species collected from managed and unmanaged types were the same (20 species). In detail, the number of species at canopy level was smaller than at ground level in managed pine forests (11 and 19), while the number of species collected at canopy level was larger than at ground level in unmanaged pine forests (17 at canopy and 14 species at ground level). When these levels were combined or separated, no significant difference was found in the number of species per trap between the two levels in managed and unmanaged types of forest (Kruskal-Wallis test and Wilcoxon test, $P > 0.05$) (Fig. 4).

Other forests. The number of species in other forests was lower than that in pine forests, namely, deciduous (12), evergreen (9) and sugi (4) (Table 3 and 6). Halictidae and Apidae showed lower numbers of species in other forests than in pine forests. In other forests, Apidae exhibited a higher number of species per trap

Table 5. List of the bees collected from the pine (managed + unmanaged) forest

Family	Species	Bee code	Managed + Unmanaged (6)		
			C(12)	C(12)	T(24)
Andrenidae	<i>Andrena japonica</i>	3	0.33 (4)	0.16 (2)	0.25 (6)
	<i>A. kaguya</i>	6	0.41 (5)	0.66 (8)	0.54 (13)
	Number of individuals	-	0.75 (9)	0.83 (10)	0.8 (19)
	Number of species	-	0.16 (2)	0.16 (2)	0.08 (2)
Apidae	<i>Bombus ardens ardens</i>	5	0.58 (7)	0.08 (1)	0.33 (8)
	<i>B. diversus diversus</i>	1	7.83 (94)	5.66 (68)	6.75 (162)
	<i>B. hypocrita hypocrita</i>	7	0.75 (9)	0.25 (3)	0.5 (12)
	<i>B. ignitus</i>	2	1.16 (14)	0.33 (4)	0.75 (18)
	<i>Ceratina japonica</i>	11	0.41 (5)	0.16 (2)	0.29 (7)
	<i>Tetralonia mitsukurii</i>	24	0 (0)	0.08 (1)	0.04 (1)
	<i>Xylocopa appendiculata circumvolans</i>	25	0 (0)	0.08 (1)	0.04 (1)
	Number of individuals	-	10.75 (129)	6.67 (80)	8.7 (209)
Number of species	-	0.41 (5)	0.58 (7)	0.29 (7)	
Halictidae	<i>Lasioglossum amamiense</i>	14	0.08 (1)	0.08 (1)	0.08 (2)
	<i>L. japonicum</i>	4	0.91 (11)	0.83 (10)	0.87 (21)
	<i>L. kuroshio</i>	8	0.41 (5)	0.75 (9)	0.58 (14)
	<i>L. mutillum</i>	15	0 (0)	0.16 (2)	0.08 (2)
	<i>L. nipponicola</i>	16	0.08 (1)	0.08 (1)	0.08 (2)
	<i>L. occidens</i>	17	0.16 (2)	0.08 (1)	0.12 (3)
	<i>L. ohei</i>	18	0 (0)	0.08 (1)	0.04 (1)
	<i>L. primavera</i>	19	0 (0)	0.08 (1)	0.04 (1)
	<i>L. proximum</i>	9	0.33 (4)	0.25 (3)	0.29 (7)
	<i>L. sibiriacum</i>	20	0.25 (3)	0.16 (2)	0.2 (5)
	<i>Lasioglossum</i> sp.	21	0.08 (1)	0.08 (1)	0.08 (2)
	<i>L. villosulum trichopse</i>	22	0 (0)	0.08 (1)	0.04 (1)
	<i>L. vulsum</i>	10	0.33 (4)	0.08 (1)	0.2 (5)
	<i>Sphecodes</i> sp.	23	0.08 (1)	0 (0)	0.04 (1)
	Number of individuals	-	2.75 (33)	2.83 (34)	2.79 (67)
Number of species	-	0.83 (10)	1.08 (13)	0.58 (14)	
Colletidae	<i>Hylaeus floralis</i> Smith	13	0.08 (1)	0 (0)	0.04 (1)
Megachilidae	<i>Coelioxys yanonis</i> Matsumura	12	0 (0)	0.08 (1)	0.04 (1)
Total no. of individuals			11.2 (45)	5.5 (22)	14.3 (172)
Total no. of species			4.7 (12)	2.2 (4)	5.4 (18)

Abbreviations see Table 3.

than other families (Kruskal-Wallis test, $P < 0.05$) (Fig. 5). The second ranked family for the number of species in evergreen and sugi forests was Halictidae, while in deciduous forests, it was Andrenidae. All families showed a higher number of species at canopy than at ground level in each type of forest. In other forests, the number of species was larger at canopy (12 species in deciduous, 7 in evergreen and 4 in sugi) than at ground level (4, 5 and 0).

7. Abundance at species level

7.1. All forests

The four most abundant species collected were *Bombus diversus* (53.28%), *B. ignitus* (7.98), *Lasioglossum japonicum* (6.8) and *Andrena kaguya* (5.63) (the percentages in parentheses are the proportions of the total number of individuals in the sample). *B. diversus* was also the most abundant species in all forest types. In addition, seven singleton species and four doubleton species were collected (Table 6).

The abundances of the top four ranking species were higher at canopy (128, 27, 18 and 14 individuals for *B. diversus*, *B. ignitus*, *Lasioglossum japonicum* and *Andrena kaguya*, respectively) than at ground level (99, 7, 11 and 10). Most bee species was more abundant at canopy than at ground level (Table 6). Nevertheless, four species were less abundant at canopy than at ground level, namely, *L. kuroshio* (6 and 11 individuals at canopy and ground levels, respectively), *L. mutillum* (1 and 2), *Coelioxys yanonis* (0 and 1), *Xylocopa appendiculata* (0 and 1) and *Tetralonia mitsukurii* (0 and 1).

7.2. Each forest type

Pine forest. In pine forests, *B. diversus* was the most abundant (162 individuals and 6.75 per trap), followed by *L. japonicum* (21 and 0.87) and *B. ignitus* (18 and 0.75). The abundance of *B. diversus* was higher at canopy than at ground level (94 and 68 individuals, respectively) (Table 4). Whether the layers were combined or separated, *B. diversus* was significantly more abundant in both managed and unmanaged pine forests (Kruskal-Wallis test, $P < 0.0001$) (Fig. 6). The abundance of *B. diversus* was not significantly different between the canopy and ground levels in both managed and unmanaged pine forests (Kruskal-Wallis test, $P > 0.05$) (Fig. 6). The second most abundant species was *L. kuroshio* (12) in managed pine forests and *L. japonicum* (12) in unmanaged ones (Fig. 6). The abundance of each bee species was not significantly different either between canopy and ground layers or between managed and unmanaged types (Kruskal-Wallis test, $P > 0.05$) (Fig. 6).

Other forests. Similar to the case in pine forests, *B. diversus* was significantly more abundant than other species irrespective of whether ground and canopy levels were combined or separated in other forest types (Kruskal Wallis test, $P < 0.0001$) (Table 3, 6 and Fig. 6). The second and third most abundant species in the other three forest types were not the same: in evergreen and sugi forests, *B. ignitus* (10 and 2 individuals, respectively) and *B. ardens* (6 and 1) were the second and third most abundant species, respectively. Meanwhile, in deciduous forests, the second and third most abundant species were *A. kaguya* (11) and *B. hypocrita* (6), respectively. The abundance of these species was greater at canopy than at ground level in each forest type.

Table 6. List of the bees collected from the sugi forest and total data on different forest types

Family	Species	Bee code	Sugi (1)			Grand Total (11)		
			C(2)	G(2)	T(4)	C(22)	G(22)	T(44)
Andrenidae	<i>Andrena japonica</i>	3	0 (0)	0 (0)	0 (0)	0.27 (6)	0.13 (3)	0.2 (9)
	<i>A. kaguya</i>	6	0 (0)	0 (0)	0 (0)	0.63 (14)	0.45 (10)	0.54 (24)
	Number of individuals	-	0 (0)	0 (0)	0 (0)	0.9 (20)	0.6 (13)	0.75 (33)
	Number of species	-	0 (0)	0 (0)	0 (0)	0.09 (2)	0.09 (2)	0.09 (2)
Apidae	<i>Bombus ardens ardens</i>	5	0.5 (1)	0 (0)	0.25 (1)	0.63 (14)	0.09 (2)	0.36 (16)
	<i>B. diversus diversus</i>	1	1.5 (3)	0 (0)	0.75 (3)	5.81 (128)	4.5 (99)	5.15 (227)
	<i>B. hypocrita hypocrita</i>	7	0 (0)	0 (0)	0 (0)	0.68 (15)	0.18 (4)	0.43 (19)
	<i>B. ignitus</i>	2	1 (2)	0 (0)	0.5 (2)	1.22 (27)	0.31 (7)	0.77 (34)
	<i>Ceratina japonica</i>	11	0 (0)	0 (0)	0 (0)	0.27 (6)	0.09 (2)	0.18 (8)
	<i>Tetralonia mitsukurii</i>	24	0 (0)	0 (0)	0 (0)	0 (0)	0.04 (1)	0.02 (1)
	<i>Xylocopa appendiculata circumvolans</i>	25	0 (0)	0 (0)	0 (0)	0 (0)	0.04 (1)	0.02 (1)
	Number of individuals	-	3 (6)	0 (0)	1.5 (6)	8.63 (190)	5.27 (116)	6.95 (306)
	Number of species	-	1.5 (3)	0 (0)	0.75 (3)	0.22 (5)	0.31 (7)	0.15 (7)
Halictidae	<i>Lasioglossum amamiense</i>	14	0 (0)	0 (0)	0 (0)	0.04 (1)	0.04 (1)	0.04 (2)
	<i>L. japonicum</i>	4	0 (0)	0 (0)	0 (0)	0.81 (18)	0.5 (11)	0.65 (29)
	<i>L. kuroshio</i>	8	0 (0)	0 (0)	0 (0)	0.27 (6)	0.5 (11)	0.38 (17)
	<i>L. mutilum</i>	15	0.5 (1)	0 (0)	0.25 (1)	0.04 (1)	0.09 (2)	0.06 (3)
	<i>L. nipponicola</i>	16	0 (0)	0 (0)	0 (0)	0.04 (1)	0.04 (1)	0.04 (2)
	<i>L. occidens</i>	17	0 (0)	0 (0)	0 (0)	0.09 (2)	0.04 (1)	0.06 (3)
	<i>L. ohei</i>	18	0 (0)	0 (0)	0 (0)	0 (0)	0.04 (1)	0.02 (1)
	<i>L. primavera</i>	19	0 (0)	0 (0)	0 (0)	0.04 (1)	0.04 (1)	0.04 (2)
	<i>L. proximatium</i>	9	0 (0)	0 (0)	0 (0)	0.31 (7)	0.13 (3)	0.22 (10)
	<i>L. sibiriacum</i>	20	0 (0)	0 (0)	0 (0)	0.13 (3)	0.09 (2)	0.11 (5)

Table 6 (continued)

Family	Species	Bee code	Sugi (1)			Grand Total (11)		
			C(2)	G(2)	T(4)	C(22)	G(22)	T(44)
	<i>Lasioglossum</i> sp.	21	0 (0)	0 (0)	0 (0)	0.04 (1)	0.04 (1)	0.04 (2)
	<i>L. villosulum trichopse</i>	22	0 (0)	0 (0)	0 (0)	0.09 (2)	0.04 (1)	0.06 (3)
	<i>L. vulsum</i>	10	0 (0)	0 (0)	0 (0)	0.18 (4)	0.04 (1)	0.11 (5)
	<i>Sphcodes</i> sp.	23	0 (0)	0 (0)	0 (0)	0.04 (1)	0 (0)	0.02 (1)
	Number of individuals	-	0.5 (1)	0 (0)	0.25 (1)	2.18 (48)	1.68 (37)	1.93 (85)
	Number of species	-	0.5 (1)	0 (0)	0.25 (1)	0.63 (14)	0.63 (14)	0.34 (15)
Colletidae	<i>Hylaeus floralis</i>	13	0 (0)	0 (0)	0 (0)	0.04 (1)	0 (0)	0.02 (1)
Megachilidae	<i>Coelioxys yanonis</i>	12	0 (0)	0 (0)	0 (0)	0 (0)	0.04 (1)	0.02 (1)
Total no. of individuals			3.5 (7)	0 (0)	1.7 (7)	11.8 (259)	7.6 (167)	9.7 (426)
Total no. of species			3 (4)	0 (0)	1.5 (4)	4.8 (21)	3.3 (22)	4.1 (25)

Abbreviations see Table 3.

8. Inclusion relation of species richness among the forest types

Figure 7 shows the inclusion relation of species richness among the four forest types. A number of bee species in the three forest types (12 species in deciduous, 9 in evergreen and 4 in sugi forest) were also identified in pine forests. Nine species in evergreen forests were also collected in deciduous forests. The only exception was in sugi forests, for which three of the identified species were found in all forest types, but one species occurred only in pine forests. Three species collected in all forests belonged to the genus *Bombus*, including *B. diversus*, *B. ardens* and *B. ignitus*. A total of 12 species were captured only in pine forests.

9. NMDS ordination of bee assemblages among forest types

Figure 8 shows the NMDS ordination of bee assemblages among the four forest types. The bee species composition overlapped among the forest types. No significant difference was found in bee species compositions among the four forest types (ANOSIM, $r=0.1$, $P=0.07$). When the bee species composition was checked for each forest type, the bee species composition did not differ significantly between canopy and ground levels (ANOSIM, pine forest: $r=-0.1$ $P=0.9$; deciduous forest: $r=0.02$, $P=0.4$; evergreen forest: $r=0.4$, $P=0.08$; sugi forest: $r=1$ $P=0.3$).

DISCUSSION

Bee assemblages collected inside and outside forests

Bees generally prefer to inhabit areas outside of forests because flowers are abundant in open habitats (Liow *et al.*, 2001; Winfree *et al.*, 2007; Hoehn *et al.*,

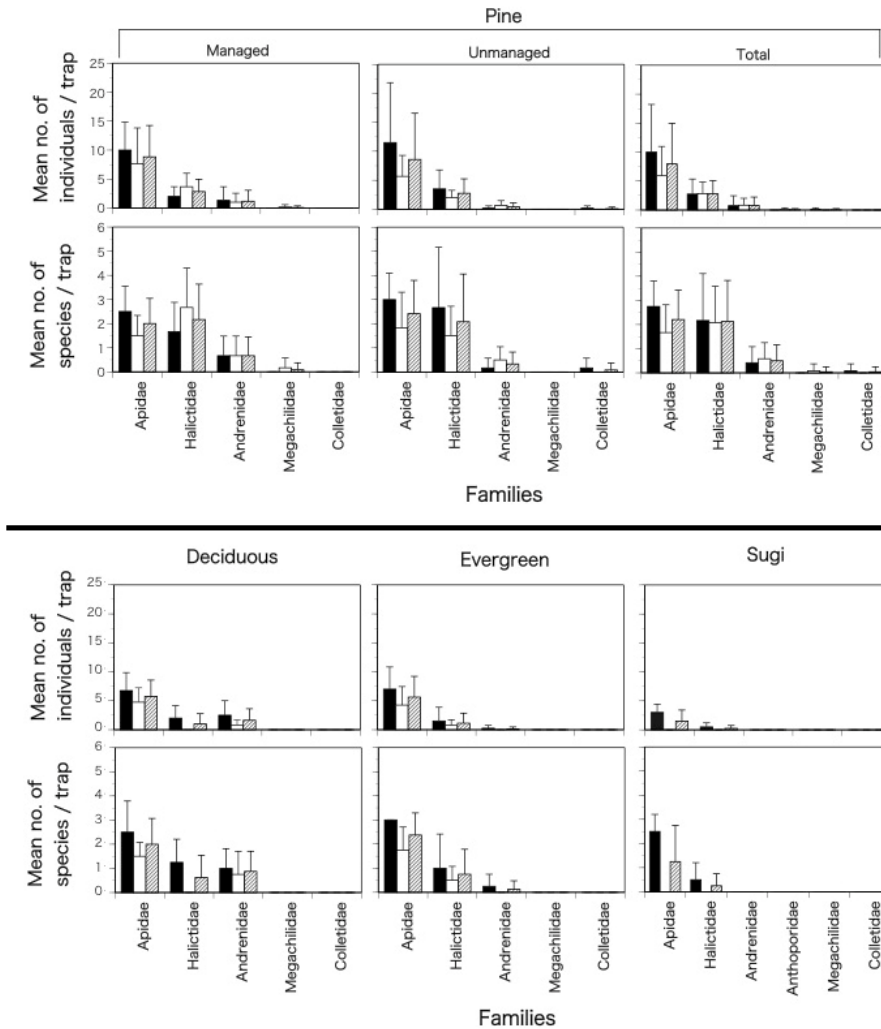


Fig. 5. Comparison of mean numbers of individuals (top) and species (bottom) in each bee family collected per trap among the four forest types (upper line column for pine and under line column for deciduous, evergreen and sugi). For pine forests, data for managed and unmanaged forests are shown separately. At canopy (■), ground (□) and both levels combined (▨). Mean (column) \pm SD (error bar) are given.

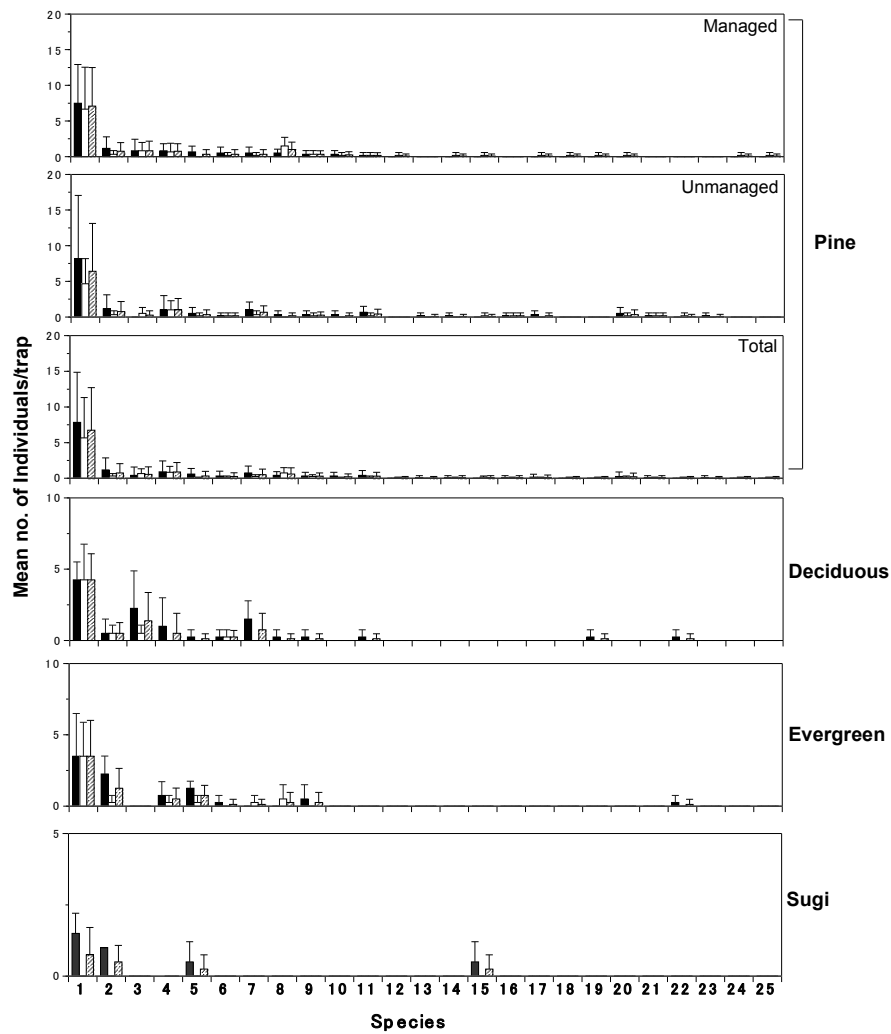


Fig. 6. Comparison of the mean number of bee individuals in each species collected per trap among the four forest types. For pine forests, data for managed and unmanaged forests are shown separately. At canopy (■), ground (□) and both levels combined (▨). Mean (column) \pm SD (error bar) are given. Numbers refer to bee species codes as follows: 1. *Bombus diversus*, 2. *B. ignitus*, 3. *Andrena japonica*, 4. *Lasioglossum japonicum*, 5. *B. ardens*, 6. *A. kaguya*, 7. *B. hypocrita*, 8. *L. kuroshio*, 9. *L. proximatum*, 10. *L. vulsum*, 11. *Ceratina japonica*, 12. *Coelioxys yanonis*, 13. *Hylaeus floralis*, 14. *L. amamiense*, 15. *L. mutillum*, 16. *L. nipponicola*, 17. *L. occidentens*, 18. *L. ohei*, 19. *L. primavera*, 20. *L. sibiriacum*, 21. *Lasioglossum* sp., 22. *L. villosulum*, 23. *Sphecodes* sp., 24. *Tetralonia mitsukurii*, 25. *Xylocopa appendiculata*. See Table 3, 4, 5, 6 for detail.

2010). In the present study, we collected a total of 25 bee species using window traps from four types of forest on Noto Peninsula. We assumed that most bees were trapped while traversing the forests, while some preferred to inhabit forests for nesting and feeding. Data on the bee assemblages outside forests in the same and nearby localities are available: first, Kasagi *et al.* (2012) collected bees with insect nets from open satoyama habitats, such as forest edges, footpaths between paddy fields, roadsides and grasslands on Noto Peninsula, including in the vicinity of the present study sites. From 55 species (3148 individuals) that they collected, 18 species overlap with the present study. Second, Putra (2009) and Priawandiputra and Nakamura (unpublished data) reported comparable data from a small satoyama terraced paddy site in Kanazawa, located about 100 km southwest from the sites in this study: from 51 species (1245 individuals, Putra, 2009) and 61 species (1870 individuals, Priawandiputra and Nakamura, unpublished data), 16 and 19 species, respectively, overlap with the present study. Pooling these data, all 25 species collected in the present study, except four singleton and doubleton species, were also recorded in these three studies. The most abundant large species in the present study, *Bombus diversus* (Apidae), was also abundant in the samples collected outside forests, namely, 5th, 2nd and 10th ranked in the studies by Kasagi *et al.* (2012), Putra (2009) and Priawandiputra and Nakamura (unpublished data), respectively. Large-sized *Bombus* species, like *B. diversus*, are known for a wide foraging range (Westphal *et al.*, 2006; Tscheulin *et al.*, 2011; Taki *et al.*, 2012), so they can use floral resources that are far from their nest sites (McFrederick & Leubhn, 2005). *B. diversus*, *B. hypocrita* and *B. ardens* are able to traverse intervening habitats (McFrederick & Leubhn, 2005) and are abundant in widespread woodlands and farms in other localities (Nagamitsu *et al.*, 2006). In contrast, it should be noted that three abundant species collected outside forests, namely, *Apis cerana F.*, *A. mellifera L.* and *Halictus aerarius S.*, were not collected in the present study.

Comparison between bee and beetle assemblages

The bee samples dealt with in this article and the beetles in the work of Barsulo (2011) and Barsulo & Nakamura (2011) were collected using the same traps. The two orders are different taxonomically and ecologically: bees (Hymenoptera: Apiformes) consist of around 20,000 species from 9 families, with a narrow feeding guild (anthophilous) (Michener, 2000), while beetles (order Coleoptera) belong to the largest insect order, consisting of approximately 400,000 species from 500 families, with diverse feeding guilds (herbivores, xylophages, saprophages, fungivores, predators, omnivores) (Triplehorn & Johnson, 2005). In the following comparison between the bee and beetle assemblages, it should be noted that bees (the present study) were dealt with at the species level, but beetles only at the family level (Barsulo & Nakamura, 2011). In this regard, four findings should be pointed out as follows: First, bee assemblages at species level were not significantly different among the four forest types (Table 3, 4, 5, 6 and Fig. 8), while those of beetles at the family level in pine forests were clearly different from the others. In

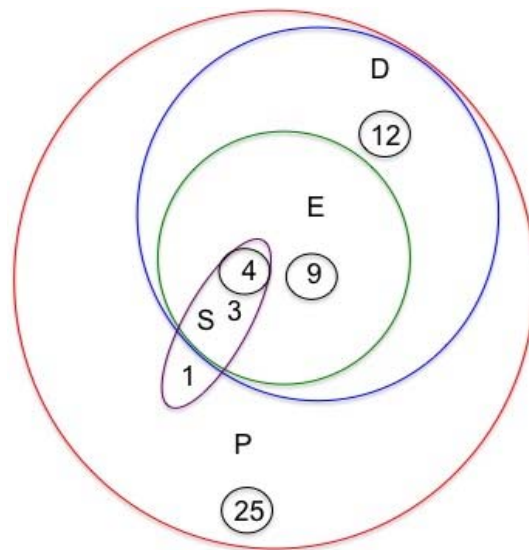


Fig. 7. Diagram showing the overlap of bee species collected from four forest types (pine, P, —; deciduous, D, —; evergreen, E, —; sugi, S, —). The numbers inside black circles indicate species richness found in each forest type, while the numbers outside black circles refer to species richness shared between forest types. See the explanation in the text regarding the numbers in the figure.

both bees and beetles, the highest numbers of species (25) and families (51), respectively, were collected from pine forests (managed and unmanaged sites are pooled). Although the numbers of sampling sites among the forest types differed, the accumulation curves for the numbers of species (see Fig. 3) and families over the sampling efforts support this conclusion. Second, the average number of individuals collected per trap was highest in pine forest (12.4 individuals/trap), followed by deciduous (8.4), evergreen (6.9) and sugi forests (1.7). Meanwhile, that of beetle individuals per trap was highest in deciduous forest (148.7), followed by pine (123.2), evergreen (84.2) and sugi (19.7). The species richness and abundance of bees were found to be highest in pine forest, probably because it is sparser and well lighted, which bees prefer over other forest types, while deciduous forests might provide more diverse food resources for diversified beetle assemblages. In contrast, the species richness and abundance of bees and beetles in sugi forests, which are monotonous and dark, were the lowest. Third, to compare the forest strata, the number of species and abundance of bees were higher at canopy than at ground level for all forest types (Fig. 4). Meanwhile, beetles did not show a consistent tendency in these aspects between layers, that is, canopy showed higher values than ground level in pine forests, but the opposite was found in deciduous forests (Barsulo & Nakamura, 2011). Fourth, no significant difference was found in abundance and species richness in both bee (Fig. 4 and Fig. 8) and beetle assemblages

between managed and unmanaged pine forests because sites of these two types were located nearby, within easy reach considering the flight ability of bees and beetles (Barsulo & Nakamura, 2011; Maeto *et al.*, 2002; Tscheulin *et al.*, 2011), and the management activities were rather mild in the study area.

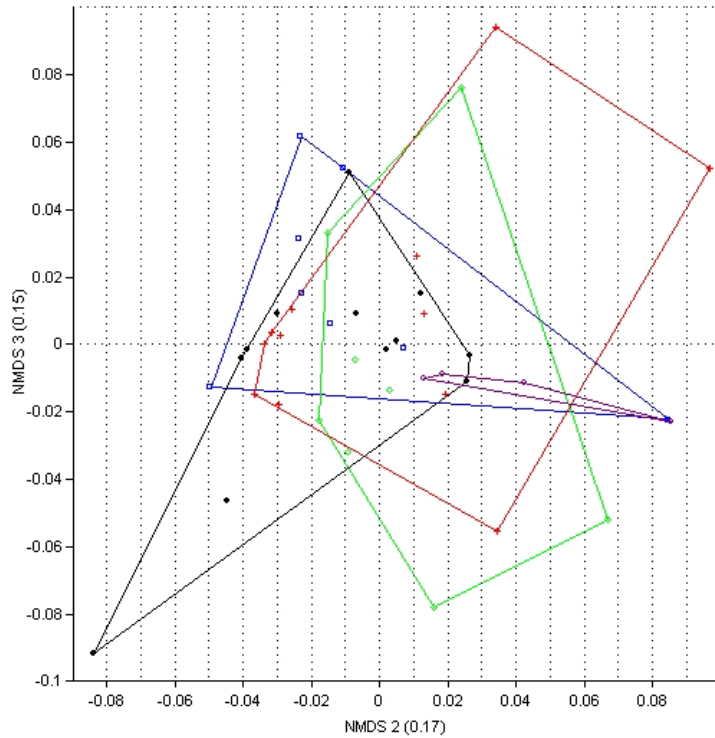


Fig. 8. Non-metric multidimensional (NMDS) ordination based on the Bray-Curtis similarity, using bee species composition of the four forest types (managed pine, — ; unmanaged pine, — ; deciduous, — ; evergreen, — ; sugi, — ; 3D-NMDS, stress=0.207).

ACKNOWLEDGEMENTS

We wish to express our sincere thanks to the following individuals and institutions for their support and encouragement in the course of this study: The Satoyama-Satoumi Project of Kanazawa University, especially to all staff at Noto Satoyama Meister Training Program, and all members of the Laboratory of Ecology, Graduate School of Natural Science and Technology, Kanazawa University; and Dr. Rizalita Edpalina and Dr. Tetsuya Kasagi for their useful advice and comments on an earlier version of this manuscript. This study was supported partly by a Monbukagakusho Scholarship to WP and a special grant for "Noto Satoyama Satoumi Reactivation Research Project" from the Ministry of Education, Culture, Sports, Science and Technology (Monbukagakusho) to KN.

REFERENCES

- Barsulo, C.Y. & Nakamura, K. 2011. Abundance and diversity of flying beetles (Coleoptera) collected by window traps in satoyama pine forests in Noto Peninsula, Japan, with special reference to the management conditions: a family level analysis. *Far Eastern Entomologist* 222: 1-23.
- Barsulo, C.Y. 2011. *Diversity and structure of flying beetle (Insecta: Coleoptera) assemblages in satoyama of Noto Peninsula*. Ph.D Dissertation, Kanazawa University, Kanazawa, Japan.
- Brosi B.J., Daily, G.C. & Ehrlich, P.R. 2007. Bee community shifts with landscape context in a tropical countryside. *Ecological Applications* 17(2): 418–430.
- Hammer, Ø., Harper, D.A.T. & Ryan, P.D. 2001. PAST: paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* 4(1): 9pp. http://palaeo-electronica.org/2001_1/past/issue1_01.htm.
- Hoehn, P., Steffan-Dewenter, I. & Tschamtkke, T. 2010. Relative contribution of agroforestry, rainforest and openland to local and regional bee diversity. *Biodiversity Conservation* 19: 2189-2200.
- James, R.R. & Pitts-Singer, T.L. 2008. *Bee pollination in agricultural ecosystems*. Oxford University Press, Oxford, United Kingdom.
- Japan Satoyama Satoumi Assessment (JSSA). 2010. *Satoyama-Satoumi Ecosystems and Human Well-being: Socio-ecological Production Landscapes of Japan – Summary for Decision Makers*. United Nations University, Tokyo, Japan.
- Kasagi, T., Ohmiya, S.T., Kimura, K., Kaneko, Y., Homma, K., Yumoto, T. & Nakamura, K. 2012. Fauna and distribution of bees in Noto Peninsula and Sado Island. *Japan Sea Research* 43: 9-17 (In Japanese).
- Kearn, C.A. & Inouye, D.W. 1993. *Techniques for pollination biologist*. University Press of Colorado, Colorado, United States.
- Kobori, H. & Primack, R.B. 2003. Participatory conservation approaches for satoyama, the traditional forest and agricultural landscape of Japan. *Ambio* 32(4): 307–311.
- Linawati, Tanabe, S., Ohwaki, A., Akaishi, D., Putra, R.E., Trisnawati, I., Kinasih, I., Kikuchi, C., Kasagi, T., Nagashima, S. & Nakamura, K. 2006. Effects of the red-pine forest management for mushroom cultivation on the ground, below- and above-ground invertebrates in Suzu, Central Japan. *Far Eastern Entomologist* 166: 1–15.
- Liow, L.H., Sodhi, N.S. & Elmqvist, T. 2001. Bee diversity along a disturbance gradient in tropical lowland forests of South-East Asia. *Journal of Applied Ecology* 38: 180–192.
- Maeto, K., Sato, S. & Miyata, H. 2002. Species diversity of longicorn beetles in humid warm- temperate forests: the impact of forest management practices on old-growth forest species in southwestern Japan. *Biodiversity and Conservation* 11: 1919–1937.
- McFrederick, Q.S. & LeBuhn, G. 2005. Are urban parks refuges for bumblebees *Bombus* spp. (Hymenoptera: Apidae). *Biological Conservation* 129(3): 372–382.
- Michener, C.D. 2000. *The Bees of the World*. John Hopkins University Press, Baltimore, United States.
- Nagamitsu, T., Kenta, T., Inari, N., Kato, E. & Hiura, T. 2006. Abundance, body size, and morphology of bumblebees in an area where an exotic species, *Bombus terrestris*, has colonized in Japan. *Ecological Research*, doi:10.1007/s11284-006-0029-5.
- Nakashizuka, T. & Stork, N. 2002. *Biodiversity research methods: IBOY in Western Pacific and Asia*. Kyoto University Press, Kyoto, Japan.

- The National Biodiversity Strategy of Japan, Ministry of Environment, Government of Japan. 2012-2020. *Roadmap towards the Establishment of an Enriching Society in Harmony with Nature*. Tokyo, Japan.
- R Development Core Team. 2008. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL. <http://www.R-project.org>.
- SAS Institute Inc. 2007. *JMP Statistics and Graphics Guide*. SAS Institute Inc, Cary, North Carolina, United States.
- Taki, H., Makihara, H., Matsumura, T., Hasegawa, M., Matsuura, T., Tanaka, H., Makino, S. & Okabe, K. 2012. Evaluation of secondary forests as alternative habitat to primary forests for flowering-visiting insects. *Journal Insect Conservation*, doi:10.1007/s10841-012-9539-3.
- Triplehorn, C.A. & Johnson, N.F. 2005. *Borror and DeLong's Introduction to the study of insects. 7th Edition*. Brooks/Cole. Belmont, CA., United States 864 pp.
- Tscheulin, T., Neokosmidis, L., Petanidou, T. & Settele, J. 2011. Influence of landscape context on the abundance and diversity of bees in Mediterranean olive groves. *Bulletin of Entomological Research* 101: 557–564.
- Putra, R.E. 2009. *Change in pollination system during restoration of Satoyama terraced paddies*. Ph.D dissertation, Kanazawa University, Japan.
- Washitani, I. 2001. Traditional sustainable ecosystem 'SATOYAMA' and biodiversity crisis in Japan: conservation ecological perspective. *Global Environment Researches* 5(2): 119–133.
- Westphal, C., Stevan-Dewenter, I. & Tscharntke, T. 2006. Bumblebees experience landscapes at different spatial scales: possible implications for coexistence. *Oecologia* 149: 289–300, doi:10.1007/s00442-006-0448-6.
- Winfree, R., Griswold, T. & Kremen, C. 2007. Effect of human disturbance on bee communities in a forested ecosystem. *Conservation Biology* 21(1): 213-223.
- Yamane, S., Ikudome, S. & Terayama, M. 1999. *Identification Guide to the Aculeata of the Nansei Islands, Japan*. Hokkaido University Press, Hokkaido, Japan.

Correspondence

hppt/ urn:lsid:zoobank.org:pub: 163E3175-0B41-4A8A-9B42-C626206387B3

E.A. Makarchenko, M.A. Makarchenko. A NEW NAME FOR *PARATRICHOCLODIUS FONTINALIS* MAKARCHENKO ET MAKARCHENKO, 2014, A SECONDARY HOMONYM OF *SYNCRICOTOPUS FONTINALIS* SÆTHER, 1969 (DIPTERA: CHIRONOMIDAE). – Far Eastern Entomologist. 2015. N 287: 23-24.

Institute of Biology and Soil Science, Far Eastern Branch of the Russian Academy of Sciences, Vladivostok, 690022, Russia. E-mail: makarchenko@biosoil.ru

Summary. A new name *Paratrichocladus scaturigineus* **nom. n.** is given for *Paratrichocladus fontinalis* Makarchenko et Makarchenko, 2014, which is secondary homonym of *Syncriotopus fontinalis* Sæther, 1969.

Key words: Chironomidae, Orhocladiinae, *Paratrichocladus*, taxonomy.