



Arboreal and Forest Floor Mites (Acari :  
Gamasida, Oribatida) Found in the Tomakomai  
Experimental Forest of Hokkaido University,  
Hokkaido, Northern Japan

メタデータ	言語: English 出版者: 公開日: 2008-05-21 キーワード (Ja): キーワード (En): 作成者: 高久, 元, 佐々木, 富也 メールアドレス: 所属:
URL	<a href="https://doi.org/10.32150/00005674">https://doi.org/10.32150/00005674</a>

Arboreal and Forest Floor Mites (Acari: Gamasida, Oribatida)  
Found in the Tomakomai Experimental  
Forest of Hokkaido University, Hokkaido, Northern Japan

TAKAKU Gen and SASAKI Tomiya

Department of Biology, Sapporo Campus, Hokkaido University of Education, Sapporo 002-8502

北海道大学苫小牧研究林に見られる樹上性および土壌性ダニ類  
(ダニ目：トゲダニ亜目，ササラダニ亜目)

高久 元・佐々木富也

北海道教育大学札幌校生物学教室

**ABSTRACT**

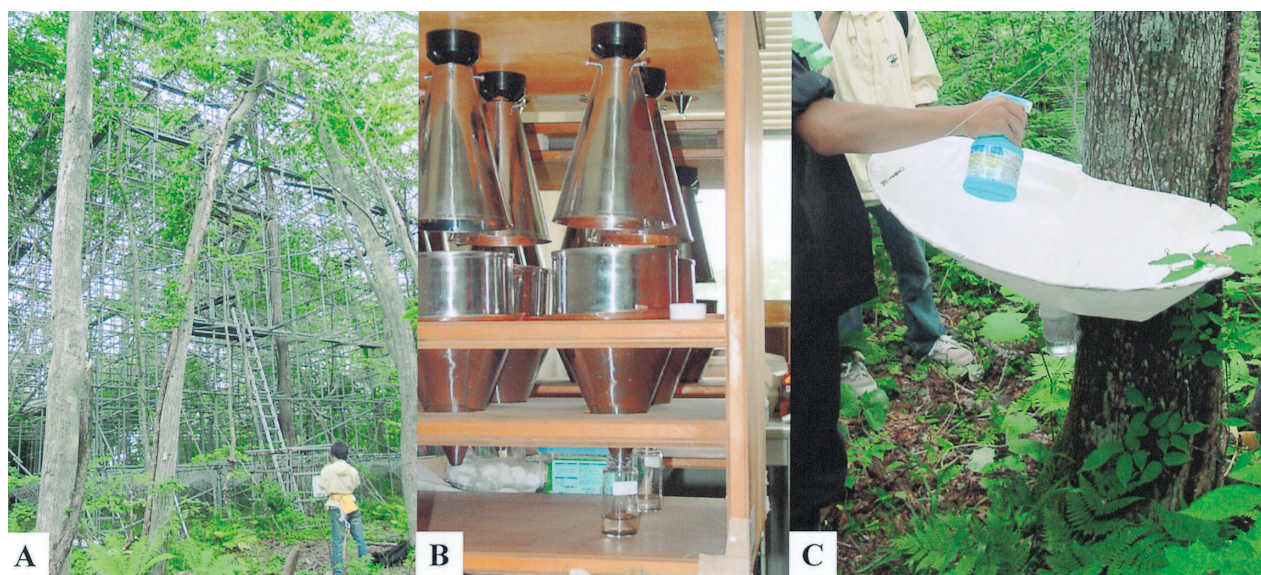
This study looks at oribatid and gamasid fauna of arboreal habitats on the oak *Quercus mongolica* var. *grosseserrata* that has been enclosed by a scaffolding system as well as mite fauna of the forest floor surrounding an oak tree adjacent to the scaffolding system in cool-temperate forest in the Tomakomai Experimental Forest of Hokkaido University, Hokkaido, northern Japan. As part of this study we collected a total of 2,596 individuals from 61 species of gamasid mites, including 6 species recorded in Japan for the first time, and 8,640 individuals in 84 species of oribatid mites. Most of the collected gamasids and oribatids were ground dwellers and inhabited the forest floor, although we did collect several species that were only found in the bark or leaves in the forest canopy. Sørensen's coefficient index and complementarity between each site indicated that the mite fauna located on bark and leaves were actually distinct from forest floor fauna. These results suggest that species specific to bark and leaves utilize these as a permanent habitat. We also found that two species of the family Phytoseiidae could only be found in the canopy leaves and 3 species of oribatid mites primarily found on bark surfaces were dominant at a particular level of the trunk and canopy. We believe this specificity to certain heights and areas may be caused by a distribution of resources (prey and organic matter), bark structure, or abiotic factors on bark surface, although additional study is necessary for elucidating these issues further.

**INTRODUCTION**

Mites (Acari) are one of the most diverse and abundant groups among the terrestrial arthropods,

with over 40,000 named species of mites and estimates for the total number of species rise to anywhere between 500,000 to one million species (Walter and Proctor, 1999). The principal habitat of mites consists of soil and litter, and these areas generally have the greatest diversity and abundances of mites (Walter and Behan-Pelletier, 1999). In addition to soil and litter, species-rich mite assemblages are also found on bark and in forest canopies. Most of the biodiversity studies that focus on the forest canopy, however, have so far tended to focus on insects, and mites have largely been ignored or grossly underestimated (Walter, 1993; Walter and Behan-Pelletier, 1999). Recent years, however, have seen this oft-overlooked animal from forest canopies and tree trunks being investigated in subtropical, tropical and temperate forests, with these studies revealing that several different kinds of mites inhabit the arboreal environments (Walter, 1993; Watanabe, 1997). Several papers have already reported that arboreal fauna is distinct from that of soil and litter (Aoki, 1973; Ito, 1986; Walter *et al.*, 1994; Winchester, 1997; Proctor *et al.*, 2002), whereas Beaulieu *et al.* (2006) suggested that tree trunks represent a highway for dispersal between habitats for most mesostigmatic mites that use them, and Watanabe (1997) noted that mites found on tree trunks or in the canopy usually migrate from the soil substratum. Aoki (1973) divided oribatid mites into 3 groups - soil forms, wandering forms, and arboreal forms - and speculated that some of these mites are restricted in the soil or arboreal environment, while some wander between the tree canopy and the soil.

Most of the above-mentioned results are based on surveys carried out in tropical, subtropical, and temperate forest, and to date there has been no comprehensive study on the arboreal mites in cool-temperate forest that is found in Hokkaido, northern Japan, except for a study on arboreal arthropod fauna in the Daisetsu mountain area of central Hokkaido (Yamashita and Ishii, 1976). The majority of studies on canopy mites in Japan have tended to focus on oribatid mites and have been carried out on conifers (Karasawa and Hijii, 2005), meaning that information regarding gamasid mites in forest canopies on broad-leaved trees remains relatively scarce, although one exception to this have been studies of phytoseiid mites as the natural enemy of spider mites. Furthermore, few studies have looked to directly com-



**Fig. 1.** A. Scaffolding system in Tomakomai Experimental Forest of Hokkaido University; B. Tullgren funnel for collecting mites from litter and soil samples; C. Bark spraying method for collecting mites from bark surface.

pare mite species that simultaneously inhabit the ground, tree trunk, and canopy (Ito, 1986; Nadkarni and Longino, 1990; Fagan *et al.*, 2006). In the present study, we looked to investigate oribatid and gamasid fauna of arboreal habitats on the oak tree (deciduous broad-leaved tree) and forest floor surrounding the trees in the cool-temperate forest in Tomakomai Experimental Forest belonging to Hokkaido University, Hokkaido, northern Japan. This study also compares fauna between sampling sites. We also discuss issues such as species richness, distinctiveness, site specificity and the distributional pattern of arboreal and ground-dwelling oribatid and gamasid mites.

## MATERIALS AND METHODS

### Research area and focal tree species

All sampling was carried out in cool-temperate forest in Tomakomai Experimental Forest of Hokkaido University (42°40'N, 141°141'E), Hokkaido, northern Japan. The experimental forest is located in Tomakomai City, approximately 60km south of Sapporo City. All mite samples were collected from leaves and bark of the oak *Quercus mongolica* var. *grosseserrata* that had been enclosed by a scaffolding system (about 15m × 15m in width, 21m in height; Fukushima *et al.*, 1998) (Fig. 1A) set in the experimental forest and from litter and soil of the forest floor surrounding different oak tree adjacent to the scaffolding system.

### Collection

All samples used in the present study were collected on 20 July, 29 August, 4 October, 1 November 2005, 15 May and 26 June 2006. Sampling of mites from the soil, leaf litter, bark surface, and leaves was carried out using the following methods.

#### 1) Sampling from soil and litter

A 10m × 10m plot was established on forest floor surrounding an oak tree adjacent to the scaffolding system. The plot was then further subdivided into 25 subplots, each 2m × 2m in size. In order to collect leaf litter samples, 10 subplots were chosen randomly from 25 subplots on each research date, and litter from a 20cm × 20cm area was taken at each chosen subplot. Every effort was made to avoid including any of the top layers of the soil as part of the litter samples. Mites were extracted from the litter samples over 3 days using Tullgren funnels with 20W light bulbs (Fig. 1B). Soil samples were collected from randomly selected 10 subplots by using a cubic sampler (5cm × 5cm × 5cm) on each research date. As far as possible, leaf litter was removed from the sampling subplot before collecting soil samples. The method used on extracting mites from soil samples was the same as for the litter samples.

#### 2) Sampling from bark surface

In an attempt to collect mites from the bark surface of oak trees, bark spraying method was employed (Nakashizuka and Stork, 2002). The collecting hoop, with a plastic screw-top container containing 70% ethanol at the base of the hoop, was pinned tightly to the bark using thumbtacks. A 0.5m × 0.5m area of bark above the edge of the hoop was sprayed thoroughly using commercial pyrethroid insecticide. After approximately 20 minutes, the sprayed area was brushed gently using a paintbrush and a number of samples - that included mites - were gathered in a container (Fig. 1C). In carrying out the sampling, every effort was made to avoid parts of the bark covered with lichen and moss. Sampling of

bark surface was carried out at heights of 5m, 10m, and 15m from the ground using the scaffolding system.

### 3) Sampling from leaves

The sampling of leaves from the oak canopy was carried out at heights of 5m, 10m, and 15m from the ground using the scaffolding system. At each sampling height, 50 leaves were randomly chosen, cut from branches, and then placed into sealable plastic bags. Mites were directly separated from leaves using forceps and a fine paintbrush under the stereoscopic microscope, and then fixed in 70% ethanol.

Regarding the method for collecting arthropods from the forest canopy, canopy knockdown, or insecticide fogging, is a well-known and popular method (Nakashizuka and Stork, 2002; Yanoviak *et al.*, 2003). This technique is efficient in surveying arthropods living on the inaccessible forest canopy. The canopy does, however, include several different microhabitats, such as leaves, bark crevices, suspended soil, lichen, and moss. Even if it were possible to collect canopy mites by canopy knockdown, it would still be difficult to precisely identify their habitat. Moreover, Yanoviak *et al.* (2003) have shown that many arthropods that are killed by insecticide remain trapped within the epiphyte material, and Watanabe (1997) indicated that repeated sampling of the same sites by insecticide smoking is difficult. As the present study is expected to clarify mite fauna in each research site and specificity to certain habitats through repeated sampling, we therefore decided to employ the direct method in collecting mites from bark surface and leaves.

All mite specimens were cleared in 60% lactic acid or Nesbitt's solution (Krantz, 1978). Gamasid mites were mounted in Hoyer's medium on glass slides and oribatid mites were mounted in lactic acid on glass slides. The mite specimens were identified to species as far as possible, and this was performed by differential interference contrast microscope.

### Similarity and complementarity of fauna between research sites

In this study we used Sørensen's coefficient index for indicating similarity of mite fauna between research sites. Sørensen's coefficient index is regarded as one of the most effective presence/absence similarity measures (Magurran, 2004). The index ( $C_S$ ) was calculated as follows:  $C_S = 2a / (2a + b + c)$ : a, the total number of species present in both sites; b, the number of species present only in one site; c, the number of species present only in the other site. The index ranges from zero (no overlap) to 1 (same species composition).

We also calculated the Marczewski-Steinhaus distance (Magurran, 2004) as a measure of complementarity in ground vs. canopy mite fauna in comparing these with results of any previous studies. We calculated complementarity ( $C_{MS}$ ) is calculated as follows:  $C_{MS} = 1 - a / (a + b + c)$ : variables that are the same as for Sørensen's coefficient index. The complementarity ranges from zero (same species composition) to 1 (no overlap).

### Site specificity

In order to clarify the site specificity of mites, each mite species was assigned to one of the following 4 categories: 1) Ground dweller: Species collected from only forest floor (soil and litter); 2) Bark specialist: Species exclusively collected from bark; 3) Foliar specialist: Species primarily found on leaves; 4) Generalist: Species collected from both forest floor and bark.

To verify whether species collected from bark and leaves were distributed among a certain height of

**Table 1.** Abundance of the gamasid mite species collected from each study site (all sampling dates are pooled) .  
\*: species recorded from Japan for the first time.

Superfamily	Family	Species name	Abundance				
			Soil	Litter	Bark	Leaves	
Parasitoidea	Parasitidae	* <i>Neogamasus davydovae</i> Volonikhina, 1993	13	4	0	0	
		* <i>Neogamasus insularius</i> Volonikhina, 1993	9	7	0	0	
		<i>Neogamasus</i> sp. 1	7	3	0	0	
		<i>Neogamasus</i> sp. 2	5	25	0	0	
		<i>Neogamasus</i> sp. 3	2	0	0	0	
		Parasitidae sp.	2	0	0	0	
	Veigaiidae	<i>Gamasolaelaps ctenisetiger</i> Ishikawa, 1978	4	3	0	0	
		<i>Veigaia kawasawai</i> Ishikawa, 1982	5	30	0	0	
		* <i>Veigaia ochracea</i> Bregetova, 1961	22	3	0	0	
		<i>Veigaia uenoi</i> Ishikawa, 1972	2	2	0	0	
	<i>Veigaia</i> sp.	1	0	0	0		
Rhodacaroidea	Digamasellidae	* <i>Dendrolaelaps armatus</i> Hirschmann, 1960	1	0	0	0	
		<i>Dendrolaelaps fukikoeae</i> Ishikawa, 1977	0	2	0	0	
	Ologamasidae	<i>Gamasiphis</i> sp.	23	82	0	0	
Ascoidea	Ascidae	<i>Antemoseius japonicus</i> Ishikawa, 1979	0	89	0	0	
		<i>Asca aphidioides</i> (Linnaeus, 1758)	6	25	0	0	
		<i>Asca nubes</i> Ishikawa, 1969	3	111	9	0	
		<i>Asca sculptrata</i> Aoki, 1968	2	16	0	0	
		<i>Lasioseius sugawarai</i> Ehara, 1964	3	1	0	0	
		<i>Lasioseius tomokoae</i> Ishikawa, 1969	0	1	0	0	
		<i>Lasioseius</i> sp.	0	0	5	0	
		<i>Leioseius brevisetosus</i> Ishikawa, 1969	0	18	0	0	
		<i>Leioseius</i> sp. near <i>insignis</i> Hirschmann, 1963	6	185	0	0	
		<i>Zerconopsis sinuata</i> Ishikawa, 1969	1	0	0	0	
	Zerconidae	* <i>Neozercion insularis</i> Petrova, 1977	0	5	0	0	
		<i>Zercion armatus</i> Aoki, 1966	7	0	0	0	
		<i>Zercion japonicus</i> Aoki, 1964	1	0	0	0	
		<i>Zercionidae</i> sp.	16	0	0	0	
Phytoseioidea	Phytoseiidae	<i>Amblyseius ishizuchiensis</i> Ehara, 1972	1	85	0	0	
		<i>Amblyseius orientalis</i> Ehara, 1959	0	0	1	9	
		<i>Euseius finlandicus</i> (Oudemans, 1915)	0	0	0	319	
		<i>Euseius sojaensis</i> (Ehara, 1964)	0	3	0	0	
		<i>Neoseiulus repletus</i> (Wu & Li, 1985)	0	0	0	6	
		<i>Neoseiulus</i> sp. near <i>haimatus</i> (Ehara, 1967)	0	2	0	0	
		<i>Phytoseius (Dubininellus) blakistoni</i> Ehara, 1966	0	1	0	10	
		<i>Typhlodromus (Anthoseius) vulgaris</i> Ehara, 1959	0	0	0	37	
	Ameroseiidae	<i>Epicriopsis stellata</i> Ishikawa, 1972	0	10	0	0	
	Podocinidae	<i>Podocinum aoki</i> Ishikawa, 1970	1	28	0	0	
		<i>Podocinum catenum</i> Ishikawa, 1970	1	16	0	0	
	Epicriidae	<i>Epicrius nemorosus</i> Ishikawa, 1969	1	2	0	0	
	Eviphidoidea	Macrochelidae	<i>Macrocheles serratus</i> Ishikawa, 1968	0	2	0	0
		Parholaspidae	<i>Gamasholaspis akimotoi</i> (Ishikawa, 1966)	12	1	0	0
<i>Gamasholaspis browningi</i> (Bregetova & Koroleva, 1960)			2	1	0	0	
<i>Parholaspulus alstoni</i> Evans, 1956			2	1	0	0	
<i>Parholaspulus arboreus</i> Ishikawa, 1980			0	0	4	0	
<i>Parholaspulus communis</i> (Ishikawa, 1966)			1	0	0	0	
<i>Parholaspulus dentatus</i> Ishikawa, 1969			62	4	0	0	
<i>Parholaspulus ochraceus</i> (Ishikawa, 1966)			69	24	0	0	
<i>Parholaspulus</i> sp.			86	0	0	0	
Dermanyssoidea	Laelapidae	* <i>Hypoaspis vacua</i> (Michael, 1891)	14	3	0	0	
		<i>Hypoaspis queenslandicus</i> (Womersley, 1956)	9	0	0	0	
		<i>Hypoaspis</i> sp. near <i>claviger</i> (Berlese, 1883)	0	1	0	0	
		<i>Hypoaspis</i> sp.	4	0	0	0	
	Unknown	<i>Neoparasitus punctatus</i> Ishikawa, 1987	2	1	0	0	
Uropodoidea	Uropodidae	<i>Dinychus kurosai</i> Hiramatsu, 1978	1	6	0	0	
		Uropodidae sp. 1	7	28	0	0	
		Uropodidae sp. 2	3	4	0	0	
		Uropodidae sp. 3	0	1	0	0	
		Uropodidae sp. 4	113	12	0	0	
		Uropodidae sp. 5	13	0	0	0	
		Uropodidae sp. 6	1	0	0	0	
	Larvae	8	31	1	20		
	Nymphs	274	408	12	38		
	Undetermined	4	4	2	0		
Total			832	1291	34	439	

**Table 2.** Abundance of the oribatid mite species collected from each study site (all sampling dates are pooled) .

Superfamily	Family	Species name	Abundance			
			Soil	Litter	Bark	Leaves
Brachychthonioidea	Brachychthoniidae	<i>Liochthonius strenzkei</i> Forsslund, 1963	1	17	0	0
		<i>Poecilochthonius spiciger</i> (Berlese, 1910)	1	4	0	0
Hypochthonioidea	Hypochthoniidae	<i>Eohypochthonius magnus</i> Aoki, 1977	199	586	0	0
		<i>Hypochthonius rufulus</i> C. L. Koch, 1836	73	185	0	0
Eniochthonioidea	Eniochthoniidae	<i>Hypochthoniella minutissima</i> (Berlese, 1904)	126	206	0	0
Mesoplophoroidea	Mesoplophoridae	<i>Mesoplophora (Parplophora) japonica</i> Aoki, 1970	51	7	0	0
Lohmannioidea	Lohmanniidae	<i>Papillacarus hirsutus</i> (Aoki, 1961)	63	0	0	0
Eulohmannioidea	Eulohmanniidae	<i>Eulohmannia ribagai</i> Berlese, 1910	28	0	0	0
Epilohmannioidea	Epilohmanniidae	<i>Epilohmannia spathulata</i> Aoki, 1970	7	0	0	0
		<i>Epilohmannia</i> sp.	5	0	0	0
Phthiracaroida	Phthiracaridae	<i>Phthiracarus bryobius</i> Jacot, 1930	0	1	0	0
		<i>Phthiracarus japonicus</i> Aoki, 1958	0	2	3	0
		<i>Phthiracarus setosus</i> (Banks, 1895)	3	0	0	0
		<i>Phthiracarus</i> sp. 2	20	36	0	0
		<i>Phthiracarus</i> sp. 3	1	0	0	0
	Steganacaridae	<i>Atropacarus (Atropscarus) striculus</i> (C. L. Koch, 1836)	141	38	0	0
Euphthiracaroida	Euphthiracaridae	<i>Rhysotritia ardua</i> (C. L. Koch, 1841)	24	67	2	0
Crotonioidea	Camisiidae	<i>Camisia lapponica</i> (Trägårdh, 1910)	9	0	0	0
		<i>Camisia segnis</i> (Hermann, 1804)	0	1	20	0
		<i>Platynothrhus yamasakii</i> (Aoki, 1958)	1	17	0	0
	Malaconothridae	<i>Malaconothrus japonicus</i> Aoki, 1966	118	66	2	0
		<i>Malaconothrus pygmaeus</i> Aoki, 1969	59	26	0	0
	Nothridae	<i>Nothrus biciliatus</i> C. L. Koch, 1841	125	5	0	0
<i>Nothrus palustris</i> C. L. Koch, 1839		7	2	0	0	
<i>Nothrus silvestris</i> Nicolet, 1855		14	5	0	0	
Nanhermannioidea	Nanhermanniidae	<i>Nanhermannia elegantula</i> Berlese, 1913	12	0	0	0
Gymnodamaeoida	Pedrocortesellidae	<i>Hexachaetoniella japonica</i> (Aoki & Suzuki, 1970)	0	1	33	0
Damaeoida	Damaeidae	<i>Belba</i> sp. 1	0	8	0	0
		<i>Belba</i> sp. 2	17	0	0	0
		<i>Belba</i> sp. 3	2	1	0	0
		<i>Epidamaeus angulatus</i> Fujikawa & Fujita, 1985	1	0	0	0
		<i>Epidamaeus grandjeani</i> Bulanova-Zachvatkina, 1957	1	0	11	0
		Damaeidae sp. 1	13	9	0	0
		Damaeidae sp. 2	0	1	0	0
Cepheoidea	Cepheidae	<i>Cepheus cepheiformis</i> (Nicolet, 1855)	0	0	9	0
Eremuloidea	Ameridae	<i>Caenosamerus spatiosus</i> Aoki, 1977	0	1	0	0
	Damaeolidae	<i>Fosseremus quadripertitus</i> Grandjean, 1965	6	1	0	0
	Eremobelbidae	<i>Eremobelba japonica</i> Aoki, 1959	30	36	0	0
	Eremulidae	<i>Eremulus avenifer</i> Berlese, 1913	0	1	0	0
Liacaroida	Astegistidae	<i>Cultroribula lata</i> Aoki, 1961	91	744	0	0
	Metrioppiidae	<i>Ceratoppia bipilis</i> (Hermann, 1804)	4	34	0	0
		<i>Ceratoppia quadridentata</i> (Haller, 1882)	19	34	0	0
		<i>Ceratoppia</i> sp.	0	0	162	0
	Xenillidae	<i>Xenillus tegeocranus</i> (Hermann, 1804)	1	7	0	0
Carabodoidea	Carabodidae	<i>Carabodes peniculatus</i> Aoki, 1970	0	1	0	0
	Otocephelidae	<i>Fissicepheus clavatus</i> (Aoki, 1959)	0	1	0	0
		<i>Fissicepheus</i> sp.	0	2	0	0
Tectocephoidea	Tectocephelidae	<i>Tectocephus cuspidentatus</i> Knülle, 1954	3	6	0	0
		<i>Tectocephus velatus</i> (Michael, 1880)	15	39	7	0
Oppioidea	Oppiidae	<i>Lauroppia decempectinata</i> (Fujikawa, 1986)	1	1	0	0
		<i>Medioxyoppia</i> sp.	16	0	0	0
		<i>Microppia minus</i> (Paoli, 1908)	2	2	0	0
		<i>Multioppia (Multilanceoppia) brevipectinata</i> Suzuki, 1975	1	10	0	0
		<i>Oppiella nova</i> (Oudemans, 1902)	929	210	0	0
		<i>Quadroppia quadricarinata</i> (Michael, 1885)	211	4	1	0
		<i>Ramusella (Ramusella) sengbuschi</i> Hammer, 1968	1	0	0	0
		<i>Subiasella</i> sp.	1	3	0	0
Suctobelbidae	<i>Flagrosuctobelbella naginata</i> (Aoki, 1961)	199	26	0	0	
	<i>Suctobelbella tuberculata</i> Aoki, 1970	1	0	0	0	
	<i>Suctobelbella</i> sp. near <i>longisensillata</i> Fujita & Fujikawa, 1987	194	13	0	0	
Cymbaeremaeoidea	Cymbaeremaeidae	<i>Ametroproctus (Coropoculia) reticulata</i> Aoki & Fujikawa, 1972	0	1	0	0
		<i>Scapheremaeus yamashitai</i> Aoki, 1970	0	2	3	0
Passalozetoidea	Licneremaeidae	<i>Licneremaeus novaeguineae</i> Balogh, 1968	0	0	19	0

**Table 2.** (continued)

Superfamily	Family	Species name	Abundance			
			Soil	Litter	Bark	Leaves
Oripodoidea	Haplozetidae	<i>Incabates angustus</i> Hammer, 1967	1	11	0	0
		<i>Incabates major</i> Aoki, 1970	0	0	2	0
	Oribatulidae	<i>Eporibatula</i> sp. near <i>tuberosa</i> Fujikawa, 1972	0	0	24	0
		<i>Oribatula sakamorii</i> Aoki, 1970	0	0	11	0
		<i>Oribatula</i> sp.	0	1	0	0
		<i>Zygoribatula truncata</i> Aoki, 1961	0	0	2	0
		<i>Zygoribatula</i> sp.	0	1	0	0
	Oripodidae	<i>Oripoda</i> sp. near <i>pinicola</i> Aoki & Ohkubo, 1974	0	1	0	0
		<i>Truncopes</i> sp. near <i>optatus asiaticus</i> Aoki & Ohkubo, 1974	0	0	1	0
	Parakalummidae	<i>Neoribates roubali</i> (Berlese, 1910)	0	12	0	0
	Protoribatidae	<i>Transoribates</i> sp. near <i>agricola</i> (Nakamura & Aoki, 1989)	0	1	0	0
	Scheloribatidae	<i>Scheloribates latipes</i> (C. L. Koch, 1841)	5	0	0	0
	Xylobatidae	<i>Xylobates lophothrichus</i> (Berlese, 1904)	180	5	0	0
<i>Xylobates</i> sp.		1	0	0	0	
Ceratozetoidea	Ceratozetidae	<i>Ceratozetella imperatoria</i> (Aoki, 1963)	0	2	0	0
		<i>Ceratozetidae</i> sp.	1	0	0	0
	Chamobatidae	<i>Chamobates pusillus</i> (Berlese, 1895)	55	148	1	0
Phenopeloidea	Phenopelopidae	<i>Eupelops acromios</i> (Hermann, 1804)	0	1	0	0
		<i>Eupelops</i> sp. near <i>acromios</i> (Hermann, 1804)	0	0	4	0
Oribatelloidea	Oribatellidae	<i>Oribatella</i> sp.	0	2	0	0
Galumnoidea	Galumnidae	<i>Trichogalumna nipponica</i> (Aoki, 1966)	3	3	0	0
		Larvae	10	21	0	0
		Nymphs	1147	1165	223	0
		Undetermined	2	3	1	0
Total			4252	3847	541	0

**Table 3.** Number of mite species and abundance of adult mites (in parentheses) collected from each study site.

	Soil	Litter	Bark	Leaves	Total
Gamasida	43 (546)	41 (848)	3 (19)	5 (381)	61 (1,794)
Oribatida	54 (3,093)	58 (2,658)	19 (317)	0 (0)	84 (6,068)

tree, we carried out a chi-square test in a few species of gamasids and oribatids that primarily inhabited among bark and leaves.

## RESULTS

We were able to collect a total of 2,596 individuals (including 802 immature and undetermined specimens) in 61 species of gamasid mites belonging to 14 families from sampling at 4 sites (Table 1). This includes 6 species belonging to 5 families that were recorded in Japan for the first time. Regarding the oribatid mites, we collected 8,640 individuals (including 2,572 immature and undetermined specimens) in 84 species belonging to 43 families (Table 2). Most of the collected gamasid and oribatid species were recorded from soil or litter, whereas species richness and abundance in bark and leaves were relatively low (Table 3). Although we did not collect any oribatid mite from leaves, species richness and abundance of oribatid mites were both much higher than those of gamasid mites in the other 3 sites. The characteristics of fauna and dominant species or family in each site were as follows.

1) Soil: Among gamasid mites, the families Parholaspididae and Uropodidae were dominant, with over

68% of adult specimens collected from soil. In oribatid mites, approximately 38% of adults collected from soil were made up of the species of the family Oppiidae, with *Oppiella nova* being the dominant species. More than 100 individuals were recorded within several different oribatid species.

2) Litter: We found that over half (53%) of adult gamasid mites collected from leaf litter were members of the family Ascidae. Among oribatids, *Cultroribula lata* (Astegistidae) and *Eohypochthonius magnus* (Hypochthoniidae) formed 50% of adult specimens.

3) Bark: We collected 4 gamasid species - *Asca nubes*, *Lasioseius* sp. (Ascidae), *Amblyseius orientalis* (Phytoseiidae), and *Parholaspulus arboreus* (Parholaspidae) - from bark, but they had a relatively low abundance of under 10. In contrast to these findings, 19 species of oribatid mites were recorded from bark, with *Ceratoppia* sp. (Metrioppiidae) comprising over half (51%) of the adult oribatids collected from bark.

4) Leaves: Here, *Euseius finlandicus* (Phytoseiidae) was dominant and occupied 83% of gamasid mites collected from leaves. All species collected from leaves belonged to the family Phytoseiidae. We were unable to find any oribatid mites on leaves during the present study.

**Table 4.** Sørensen's coefficient index (upper) and number of species in common (below) between study sites, based on species composition of gamasid mites.

	Leaves	Bark	Litter	Soil
Leaves		0.22	0.04	0
Bark	1		0.04	0.04
Litter	1	1		0.69
Soil	0	1	29	

**Table 5.** Sørensen's coefficient index (upper) and number of species in common (below) between study sites, based on species composition of oribatid mites.

	Bark	Litter	Soil
Bark		0.23	0.16
Litter	9		0.66
Soil	6	37	

**Table 6.** Oribatid species complementarity in canopy vs. ground (data cited from Behan-Pelletier and Walter, 2000; Proctor *et al.*, 2002), and the complementarity of gamasid and oribatid species in the present study.

Location	Canopy microhabitat	Complementarity
Germany	Canopy twigs and leaves; bark	0.42
Canada	Canopy mosses	0.68
Central Japan	Canopy branches, mosses, lichens	0.85
Australia	Bark	0.97
Northern Japan: Oribatida (present study)	Bark	0.88
Northern Japan: Gamasida (present study)	Bark, leaves	0.98

### Similarity of fauna between research sites

Sørensen's coefficient index and the number of common species found between study sites were highest between soil and litter fauna in both Gamasida and Oribatida (Tables 4, 5). The index and the number of common species between ground and bark or leaves in Oribatida and Gamasida were both much lower than for those values between soil and litter. Complementarity of species composition of gamasids and oribatids between ground and canopy in the present study were 0.98 and 0.88, respectively. These figures are similar to or greater than any previously reported results (Table 6), indicating that mite fauna found on bark and leaves are distinct from forest floor fauna.

### Site specificity

In this study we found most gamasid and oribatid mites to be ground dwellers and associated with soil and leaf litter on the forest floor (Table 7). A small portion of gamasids were specific to canopy bark or leaves, and generalists, commonly occurring arboreal habitat and forest floor, were rare. A small range of oribatids was represented by bark specialists (11%) and generalists (12%). Most generalists were predominantly found in one site, such as either in the forest floor or canopy; for example, *Hexachaetoniella japonica* (Pedrocortesellidae) was collected from bark with the exception of 1 specimen taken from leaf litter, and *Oppiella quadricarinata* (Oppiidae) was collected from the forest floor with the exception of 1 specimen that was found in bark.

Chi-square test was performed on 2 species of the family Phytoseiidae that were only found on leaves in the canopy and 3 species of oribatid mites that dominated the bark surface area. The results of the test indicated that distribution of every species differed significantly based on height. *Euseius finlandicus* tended to be found on leaves in lower areas that were 5m and 10m in height, while *Typhlodromus (Anthoseius) vulgaris* was found in higher areas (15m) of the canopy (Table 8). The oribatid mite species *Ceratoppia* sp. was mainly distributed on leaves in lower areas, whereas *Hexachaetoniella japonica* and *Eporibatula* sp. near *tuberosa* were found in the higher parts of the canopy (Table 9).

**Table 7.** Number of species of ground-dweller, bark specialist, foliar specialist, and generalist in gamasid and oribatid mites (percentage of each category in parentheses indicates relative abundance) .

	Ground-dweller	Bark specialist	Foliar specialist	Generalist	Total
Gamasida	53(87%)	2(3%)	5(8%)	1(2%)	61
Oribatida	65(77%)	9(11%)	0(0%)	10(12%)	84

**Table 8.** Number of phytoseiid mites *Euseius finlandicus* and *Typhlodromus (Anthoseius) vulgaris* collected from leaves at each height.

	5m	10m	15m	
<i>Euseius finlandicus</i>	144	118	56	***
<i>Typhlodromus (Anthoseius) vulgaris</i>	4	5	28	***

\*\*\*:  $p < 0.001$  (chi-square test)

**Table 9.** Number of oribatid mites *Ceratoppia* sp., *Hexachaetoniella japonica*, and *Eporibatula* sp. near *tuberosa* collected from bark surface at each height.

	5m	10m	15m	
<i>Ceratoppia</i> sp.	65	68	29	***
<i>Hexachaetoniella japonica</i>	1	2	30	***
<i>Eporibatula</i> sp. near <i>tuberosa</i>	1	9	14	**

\*\*\*:  $p < 0.001$ ; \*\*:  $p < 0.01$  (chi-square test)

## DISCUSSION

This study revealed that species richness of gamasid and oribatid mites on the ground (soil and litter) was far higher than that of the canopy (bark and leaves). This lower diversity in the canopy may be caused by a corresponding lower availability of resources, and total organic matter is often the most important factor influencing the abundance and community structure of soil Collembola and Oribatida (Hasegawa, 2001). Organic matter may also affect fungal biomass, which is consumed by some mites. Although little data shows differences between canopy and forest floor organic matter, they differ greatly in a variety of physical and chemical characteristics (Nadkarni and Longino, 1990), and both chemistry of organic matter and decomposition rates have an important effect on the trophic relationship and community structure in soil arthropods (Berg *et al.*, 1998). Abundance and/or quality of organic matter in the canopy may determine the abundance and diversity of mites in the canopy. Greater abiotic extremes in the canopy may also result in lower diversity and abundance of mites in the canopy. Tree crowns are subjected to more extreme variability in ambient insolation, wind, desiccation, and precipitation than found in the forest understorey (Bohlman *et al.*, 1995; Fagan *et al.*, 2006). Such extreme variability and other environmental conditions affect the diversity and abundance of mites in the canopy.

The majority of gamasid and oribatid species collected in this study were ground dwellers, inhabiting the forest floor. Some were specific to bark or leaves, however, and complementarity between ground and canopy mite fauna in both gamasids and oribatids was greater here than in the results of previous studies. A study by Watanabe (1997) on arboreal arthropods collected by insecticide smoking concluded that there is no distinct difference between arboreal and ground-dwelling oribatid mites, which depend mainly on dead plant debris, in temperate forests. A number of studies, however, have revealed that most arboreal mites, especially oribatids, distribute exclusively in their habitats (Ito, 1986; Behan-Pelletier *et al.*, 1993; Walter *et al.*, 1994; Walter and Behan-Pelletier, 1999). Some gamasid mites may also use tree trunks as a permanent habitat, although most gamasids use the trunk as a highway for dispersing between habitat patches (Beaulieu *et al.*, 2006). Bark and foliar specialists of gamasids and oribatids were not discovered among forest floor samples during the sampling period in our present study, and Sørensen's coefficient indices between canopy and forest floor were quite low. These results suggest that these specialists use bark and leaves as a permanent habitat and arboreal fauna is indeed distinct from that of the forest floor.

We recorded one gamasid species (*Asca naves*) and 10 oribatid mites as coming from both the forest

floor and canopy habitat. Most generalists were, however, found predominantly in one site and rarely found in the other habitat. Whether these generalist species simply utilize the bark for dispersing or actually use these areas as a habitat for feeding and reproducing remains unknown. The canopy mites found on the ground may be as a result of random suspended soil or litter fall, while the forest floor mites found in canopy habitat may occasionally use the canopy as a temporary habitat.

In the present study, we were unable to collect any oribatid mites from canopy leaves. Although data obtained from cool-temperate forest is insufficient for discussing why there were no oribatids on leaves, there may be some plausible explanations for this result:

(1) A difference in sampling methods: Karasawa and Hijii (2005) indicated that the washing method, in which the mites were washed off leaves using a solution of water mixed with detergent, was more likely to be an effective and a relatively unbiased method for collecting oribatid mites from the canopies of broad-leaved trees in Japan. The difference in sampling method may yield a different result between the present study and previous ones. In their paper, however, the authors also tried to collect oribatids using the direct method, in which the mites were directly collected from leaves using a brush or forceps, and recorded nearly 300 individuals of 5 oribatid species from the leaves of broad-leaved trees. In addition to this particular study, Walter *et al.* (1994) used the direct method to record 28 oribatid mite species from the leaves, stem, and trunk of the musk daisy in temperate forest located in Victoria, Australia, as we performed in the present study. The results of the above-mentioned studies indicate that the direct method is not entirely useless in collecting mites from the leaves of broad-leaved trees, and the sampling method should not affect the result of the present study.

(2) Differences in climatic province: Studies on canopy mites performed in tropical, subtropical, and temperate regions, have recorded many kinds and number of oribatid mites, whereas there are few such studies covering the cool-temperate region. Yamashita and Ishii (1976) investigated arboreal arthropods in the Daitsetsu mountain range in central Hokkaido, and recorded a high percentage of Acari in their collected total. As they collected samples using canopy fogging and identified the arthropods to the order level, however, it is difficult to identify the precise habitat of such mites and compare this with the data from our present study. Although the results of our present study may be affected by a difference in climatic province, further studies and experiments, especially in the cool-temperate region, are required to determine whether a difference in climatic province affects on the distribution of oribatids in the canopy.

(3) Difference of total organic matter: The total amount of organic matter is the most important factor influencing the abundance and organization of the Collembola and Oribatida communities (Hasegawa, 2001; Fagan *et al.*, 2006). Lower diversity and abundance in bark and canopy than found in the forest floor may be due to a smaller amount of litter and other organic matter. The trunk surface of oak from which some oribatids were collected contains a small amount of suspended soil and other organic matter in fissures and crevices, while the surface of leaves have few or no organic matter available as the food for most oribatids. The fact that no oribatids were collected from leaves in our present study may be as a result of lower total organic matter. However, further study, and a detailed comparable investigation on organic matter in each site in particular, will be necessary to determine this.

We found the vertical distribution of canopy mites to be different among each species. For the phy-

toseiid mites collected from canopy leaves, *Euseius finlandicus* was distributed mainly in lower positions (5m and 10m), while *Typhlodromus vulgaris* was collected in a higher position (15m). Toyoshima and Amano (2006), investigating the vertical distribution of predatory phytoseiid mites (such as *E. finlandicus*, *T. vulgaris*, *Amblyseius orientalis*) on leaves at heights of 2m and 5m on three magnolia trees, showed that the mite number did not differ between higher and lower positions, but was significantly different between trees. *T. vulgaris* was collected from only one tree, and occurred in low numbers. As sampling from a much higher position of the tree canopy was not carried out in their study, it's difficult to compare their results with those of our current study. Winchester (1997) noted that tree height did not affect guild proportionality, and predators, comprising mainly web-constructing arachnids, seemed able to utilize the entire vertical profile of the canopy. To confirm whether the vertical distribution of predatory phytoseiid mites shown in the present study is an exceptional case, mite distribution must be investigated on several oak trees at a range of different heights.

*E. finlandicus* has been recorded in Japan in both *Quercus mongolica* var. *grosseserrata* and magnolia (Ehara, 1958; Toyoshima and Amano, 2006), and *T. vulgaris* has been found in a variety of different plants, such as citrus, plum, apple, willow, fir, and sasa bamboo (Ehara, 1959, 1962, 1964). These phytoseiid species prey on spider mites or eriophyid mites (Ehara, 1966). According to Ehara and Ohashi (2005), 7 species of spider mites have so far been recorded as being found in the oak, *Quercus* spp., in Japan. Phytoseiid mites collected from leaves in the oak canopy probably prey on spider mites or eriophyids that inhabit leaves, and the distribution of phytoseiids in the canopy may depend on the distribution of prey. We have still not identified the mites of Prostigmata collected on leaves and bark of the oak, however, and any correlation between the distribution of phytoseiids and spider mites so far remains unknown.

The oribatid mites collected from the bark surface also exhibited a species-specific distributional pattern: *Ceratoppia* sp. was found to be distributed on the bark in lower parts of tree, whereas *Hexachaetoniella japonicus* and *Eporibatula* sp. near *tuberosa* were found on the bark in higher parts of tree. Wunderle (1992) has shown that oribatid species are usually dominant at particular levels of trunk and canopy. The distribution and species richness of oribatid mites on bark is related to the type of epiphytic cover (Behan-Pelletier and Walter, 2000). Nicolai (1986) found that highly diverse fauna lived on fissured bark, although Beaulieu *et al.* (2006) concluded that bark roughness had no significant effect on abundance or species richness of mesostigmatic mites. Any specificity to certain heights found in the present study may be caused by distribution of organic matter (such as litter, fungi, moss, and lichen), bark structure (including such as smooth, fissure, and crevice), or abiotic factors (including temperature, moisture, desiccation, and insolation) on bark surface, although further study remains necessary.

## ACKNOWLEDGEMENTS

We would like to express our sincere thanks to Drs. M. J. Toda, T. Hiura, and M. Murakami (Hokkaido University) for giving us the opportunity to study this subject and for use of facilities in the Tomakomai Experimental Forest of Hokkaido University. This study was partly supported by Grant-in-Aid for Scientific Research (Nos. 15207008, 18570078) from the Japan Society for the Promotion of Scien-

ce (JSPS) and a President Grant in Aid for Research (Special Research Grant for Facilities) from Hokkaido University of Education.

## REFERENCES

- Aoki, J. 1973. Soil mites (oribatids) climbing trees. Pp. 59-65. In: Daniel, M. and Rosicky, B. (Eds) Proceedings of the 3rd International Congress of Acarology. Academia, Prague.
- Beaulieu, F., Walter, D. E., Proctor, H. E., Kitching, R. L. and Menzel, F. 2006. Mesostigmatid mites (Acari: Mesostigmata) on rainforest tree trunks: arboreal specialists, but substrate generalists? *Experimental and Applied Acarology*, 39: 25-40.
- Behan-Pelletier, V. M., Paoletti, M. G., Bissett, B. and Stinner, B. R. 1993. Oribatid mites of forest habitats in northern Venezuela. *Tropical Zoology, Special Issue*, 1: 39-54.
- Behan-Pelletier, V. M. and Walter, D. E. 2000. Biodiversity of oribatid mites (Acari: Oribatida) in tree canopies and litter. Pp. 187-202. In: Coleman, D. C. and Hendrix, P. E. (Eds) *Invertebrates as Webmasters in Ecosystems*. CAB International, Wallingford, U.K.
- Berg, M. P., Kniese, J. P., Bedaux, J. J. M. and Verhoef, H. A. 1998. Dynamics and stratification of functional groups of micro- and mesoarthropods in the organic layer of a Scots pine forest. *Biology and Fertility Soils*, 26: 268-284.
- Bohman, S. A., Matelson, T. J. and Nadkarni, N. M. 1995. Moisture and temperature patterns of canopy humus and forest floor soil of a montane cloud forest, Costa Rica. *Biotropica*, 27: 13-19.
- Ehara, S. 1958. Three predatory mites of the genus *Typhlodromus* from Japan (Phytoseiidae). *Annotationes Zoologicae Japonenses*, 31: 53-57.
- Ehara, S. 1959. Some predatory mites of the genera *Typhlodromus* and *Amblyseius* from Japan (Phytoseiidae). *Acarologia*, 1: 285-295.
- Ehara, S. 1962. Notes on some predatory mites (Phytoseiidae and Stigmaeidae). *Japanese Journal of Applied Entomology and Zoology*, 6: 53-60.
- Ehara, S. 1964. Some mites of the families Phytoseiidae and Blattisocidae from Japan (Acarina: Mesostigmata). *Journal of the Faculty of Science, Hokkaido University, Series 6, Zoology*, 15: 378-394.
- Ehara, S. 1966. A tentative catalogue of predatory mites of Phytoseiidae known from Asia, with descriptions of five new species from Japan. *Mushi*, 39: 9-30.
- Ehara, S. and Ohashi, K. 2005. A new spider mite species of *Schizotetranychus* (Acari: Prostigmata: Tetranychidae) from *Quercus gilva* in Japan. *Zootaxa*, 884: 1-5.
- Fagan, L. L., Didham, R. K., Winchester, N. N., Behan-Pelletier, V., Clayton, M., Lindquist, E. and Ring, R. A. 2006. An experimental assessment of biodiversity and species turnover in terrestrial vs canopy leaf litter. *Oecologia*, 147: 335-347.
- Fukushima, Y., Hiura, T. and Tanabe, S. 1998. Accuracy of the MacArthur-Horn method for estimating a foliage profile. *Agricultural and Forest Meteorology*, 92: 203-210.
- Hasegawa, M. 2001. The relationship between the organic matter composition of a forest floor and the structure of a soil arthropod community. *European Journal of Soil Biology*, 37: 281-284.
- Ito, M. 1986. An ecological survey on arboreal oribatid mites (Acari: Oribatida) in subalpine coniferous forest of Shiga-Kogen, Central Japan. *Edaphologia*, 35: 19-26.
- Karasawa, S. and Hijii, N. 2005. Efficiency of sampling oribatid mites (Acari: Oribatida) from the canopies of broad-leaved trees in Japan: a comparison between the washing and direct methods. *Journal of the Acarological Society of Japan*, 14: 19-24.
- Krantz, G. W. 1978. *A Manual of Acarology*. Second edition. Oregon State University Book Store, Inc., Corvallis. 509pp.
- Magurran, A. E. 2004. *Measuring Biological Diversity*. Blackwell Science Ltd. 256pp.
- Nadkarni, N. M. and Longino, J. T. 1990. Invertebrates in canopy and ground organic matter in a Neotropical montane forest, Costa Rica. *Biotropica*, 22: 286-289.
- Nakashizuka, T. and Stork, N. E. 2002. *Biodiversity Research Methods: IBOY in Western Pacific and Asia*. Kyoto University Press and Trans Pacific Press. 216pp.
- Nicolai, V. 1986. The bark of trees: thermal properties, microclimate and fauna. *Oecologia*, 69: 148-160.

- Proctor, H. C., Montgomery, K. M., Rosen, K. E. and Kitching, R. L. 2002. Are tree trunks habitats or highway? A comparison of oribatid mite assemblages from hoop-pine bark and litter. *Australian Journal of Entomology*, 41: 294-299.
- Toyoshima, S. and Amano, H. 2006. Diversity and abundance of phytoseiid mites on *Magnolia hypoleuca* Siebold et Zuccarini, a candidate source of natural enemies in natural vegetation. *Applied Entomology and Zoology*, 41: 349-355.
- Walter, D. E. 1993. Queensland's rainforest canopies - a mitey cornucopia. *Australian Entomologist*, 20: 115-116.
- Walter, D. E. and Behan-Pelletier, V. 1999. Mites in forest canopies: filling the size distribution shortfall? *Annual Review of Entomology*, 44: 1-19.
- Walter, D. E., O'Dowd, D. and Barnes, V. 1994. The forgotten arthropods: foliar mites in the forest canopy. *Memoirs of the Queensland Museum*, 36: 221-226.
- Walter, D. E. and Proctor, H. C. 1999. *Mites: Ecology, Evolution and Behaviour*. CAB International, Wallingford, U.K. 322pp.
- Watanabe, H. 1997. Estimation of arboreal and terrestrial arthropod densities in the forest canopy as measured by insecticide smoking. Pp. 401-414. In: Stork, N. E., Adis, J. and Didham, R. K. (Eds) *Canopy Arthropods*. Chapman & Hall, London.
- Winchester, N. N. 1997. Canopy arthropods of coastal Sitka spruce trees on Vancouver Island, British Columbia, Canada. Pp. 151-168. In: Stork, N. E., Adis, J. and Didham, R. K. (Eds) *Canopy Arthropods*. Chapman & Hall, London.
- Wunderle, I. 1992. Die Oribatiden-Gemeinschaften (Acari) der verschiedenen Habitate eines Buchenwaldes. *Carolinea*, 50: 79-144.
- Yamashita, Z. and Ishii, T. 1976. Basic structure of the arboreal arthropod fauna in the natural forest of Japan. *Ecological studies of the arboreal arthropod fauna, 1. Report of the Environmental Science, Mie University*, 1: 81-111.
- Yanoviak, S. P., Nadkarni, N. M. and Gering, J. C. 2003. Arthropods in epiphytes: a diversity component that is not effectively sampled by canopy fogging. *Biodiversity and Conservation*, 12: 731-741.

(高久 元 札幌校准教授)

(佐々木富也 札幌市立和光小学校教諭)