短 報（Short communication）

Social wasps collected with Malaise traps in Japanese cedar (*Cryptomeria japonica*) plantations (Hymenoptera, Vespidae)

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Abstract

Social wasps, which are important agents of ecosystem services (as predators) and disservices (as stinging pests), were collected with Malaise traps in Japanese cedar (*Cryptomeria japonica*) plantations in three regions of Japan (Tohoku, Shikoku, and Kyushu). Each region had 12 study stands that were categorized into the following four types based on the type of management: 1) unthinned, old-age stands (78–102 y; OA); 2) unthinned stands (41–51 y; UT); 3) stands thinned 2–4 y before the study (36–50 y) with felled logs left on forest floors (TL) and 4) stands similar to 3, but felled logs were removed (TR). A total of 350 individuals of 13 species (nine of Vespinae and four of Polistinae) were collected in the three regions. For Vespinae, *Vespa simillima* and *Vespula shidai* predominated in every region, making up 38-55% and 32-52% of all vespine wasps collected, respectively. Generalized linear model (GLM) analyses, in which the type of management was used as the fixed factor and regions as the blocking factor, showed that the type of management did not affect the number of species but did affect abundance of *V. simillima* and *Vl. shidai*: OA, UT and TR had larger catches over TL in the former, and OA and UT had larger catches over TL and TR in the latter. We discussed the possible reasons why these wasps did not respond positively to thinning, which was different from the results reported for other groups of insects.

Key words: hornet, yellowjacket, paper wasp, *Cryptomeria japonica*, plantation, thinning

1. Introduction

Social wasps are important agents of ecosystem services and disservices from the viewpoint of forest management. On the one hand, these wasps play roles as predators of various forest pests (Matsuura and Yamane 1990), but on the other hand stings have been serious problems among forest workers. A total of 32,341 sting accidents including six deaths occurred between 1986 and 2004 in national forests in Japan (Matsuura et al. 2005). We need to learn the abundance and species composition of social wasps in various forests as basic information to correctly access their roles because those variables are expected to change with type or management condition of the forests.

Some studies have collected social wasps using Malaise traps or attractant traps in forests in Japan. Most of these studies focused on monitoring in broad-leaved forests (e.g., Maeto and Makihara 1999, Totok et al. 2002, Yamauchi and Watanabe 2013). However, over 40% of the forested area in Japan is occupied by man-made plantations (Forest Agency 2017) and nearly half (44%) of the plantations are coniferous stands of Japanese cedar (*Cryptomeria japonica*) or hinoki cypress (*Chamaecyparis obtusa*). Because plantations generally require more intensive and frequent management than natural forests, more information on social wasps in those forests is needed so that their ecosystem services and disservices can be quantified.

Here, we report species composition of social wasps (hornets, yellowjackets, and paper wasps) based on collections using Malaise traps in Japanese cedar plantations in three different geological regions in Japan (Tohoku, Shikoku, and Kyushu). Thinning is an important procedure to produce quality logs of Japanese cedar and is known to affect abundance and assemblages of various forest insects (Taki et al. 2010), as well as stand age (Makino et al. 2007). However, responces of social wasps to the thinning of Japanese cedar plantations have scarcely been studied (Maleque et al. 2007a). Therefore, we collected specimens with Malaise traps in thinned and unthinned stands (40–50 y), and in old stands (80–100 y) to compare the abundance and assemblages of social wasps among them.

2. Materials and methods

Social wasps were collected by H. M. in 12 monoculture stands of Japanese cedar in each of three regions in Japan, that

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is, Tohoku (Yamagata Prefecture), Shikoku (Kochi Prefecture), and Kyushu (Kumamoto and Miyazaki Prefectures) in 2009 (Appendix Table 1). The 12 stands were grouped into the following four categories, each with three replicates, according to management type: 1) unthinned, old-age stands (OA: 78–102 y), 2) unthinned stands (UT: 41–51 y), 3) stands thinned 2–4 y before the study with felled logs left on forest floors (TL: 36–50 y), and 4) stands similar to 3, but felled logs were removed from the stand (TR). We used two Malaise traps with a collection bottle (Golden Owl Publishers, Lexington, MD, USA: 180 cm long, 120 cm wide, 200 cm high) at each stand, separated by approximately 50 m. The traps were set in mid-May in Tohoku, and mid-March in Shikoku and Kyushu, depending on the flight season of the social wasps and were removed in mid-October from all sites. Trapped insects were collected at intervals of 2–4 weeks: the total number of collections was five, eight, and seven in Tohoku, Shikoku, and Kyushu, respectively.

We analyzed the number of species as a randomized block design where the management type was a fixed factor and the regions were treated as the block. We used generalized linear models (GLMs) with a Poisson error distribution in R 3.3.2. (R Development Core Team 2017). We compared a model with the fixed factor and a model without the fixed factor, using the values of Akaike's information criterion (AIC) to examine the effect of management type. We also analyzed the numbers of individuals of predominant species of social wasps. Similar to the analysis of the number of species, we used a randomized block design where management type was a fixed factor and regions were treated as the block. We conducted GLMs with a Poisson error distribution and compared the models with the AIC values. We performed post-hoc analyses to examine the effects of the four management types (OS, UT, TL, and TR) when the effect of management was detected. GLMs were prepared for all combinations of the four management types and compared with the AIC values. For example, a part of the model variations was as follows: (OS UT TL TR): null model; (OS) (UT) (TL) (TR): all four types were included; (OS) (UT TL TR), (UT) (OS TL TR), (TL) (OS UT TR), and (TR) (OS UT TL): three of the four classes were combined; and so on.

3. Results

A total of 350 social wasps belonging to nine species in the subfamily Vespinae and four in the subfamily Polistinae were collected at the study sites (Table 1, Appendix Table 2). For Vespinae, *Vespa simillima* accounted for 47% of the total catch at all sites combined, followed by *Vespula shidai* (41%). These two species were predominant in all regions, accounting for 79% (Tohoku), 97% (Shikoku), and 87% (Kyushu) of vespine specimens collected in respective regions. Catches of other vespines (*Vespa analis, V. crabro, V. mandarinia, V. ducalis, Dolichovespula media, Vespula rufa,* and *Vl. flaviceps*) were much smaller than the two predominant species, and some did not occur at one or two regions. For Polistinae, *Parapolybia crocea* accounted for 74% of the total catch at all sites combined, followed by *Parapolybia varia* (16%). *P. crocea* was most abundant at Kyushu, followed by Shikoku, while only a few individuals were collected at Tohoku. Catches of the genus *Polistes* were much smaller compared with those of *Parapolybia*, and all *Polistes* specimens (*P. nipponensis* and *P. rothneyi*) were collected in Kyushu, except a single *P. nipponensis* at Tohoku.

Table 1. Numbers of social wasps collected with Malaise traps in Japanese cedar (*Cryptomeria japonica*) plantations in three regions of Japan.

Species	Region			
	Tohoku	Shikoku	Kyushu	Total
Vespinae				
Vespa simillima	23	40	57	120
Vespa ducalis	0	1	4	5
Vespa analis	0	1	3	4
Vespa crabro	0	0	1	1
Vespa mandarinia	0	0	1	1
Vespula shidai	25	46	33	104
Vespula flaviceps	1	0	4	5
Vespula rufa	7	1	0	8
Dolichovespula media	5	0	0	5
Polistinae				
Parapolybia crocea	3	18	52	73
Parapolybia varia	2	6	8	16
Polistes nipponensis	1	0	4	5
Polistes rothneyi	0	0	3	3
Total	67	113	170	350

Data are pooled for 12 study stands in each region.

Management type did not affect the number of species. The AIC value of the model with the effect of management was 138.1, whereas the model without the effect of management had a lower AIC value of 134.2 (Fig. 1). We selected two species, *V. simillima* and *Vl. shidai*, for the analysis of management type on the number of individuals because they were predominant in all regions. Management type affected the numbers of individuals of both species. The lowest AIC values (216.4 and 224.0) were obtained from the models of (OA UT TR) (TL) and (OA UT) (TL) (TR) in *V. simillima* and *Vl. shidai*, respectively, and the AIC values of the models without the effect of management of these species were 219.2 and 259.8, respectively.

4. Discussion

This study shows that *V. simillima* and *Vl. shidai* are predominant social wasps in Japanese cedar plantations in various parts of Japan. Maeto and Makihara (1999) also showed that 69% of social wasps collected with Malaise traps in a *C. japonica* stand (57 y old) were *Vl. shidai*, followed by *Vl. flaviceps* and *V. simillima* in northern Kanto, central Japan.

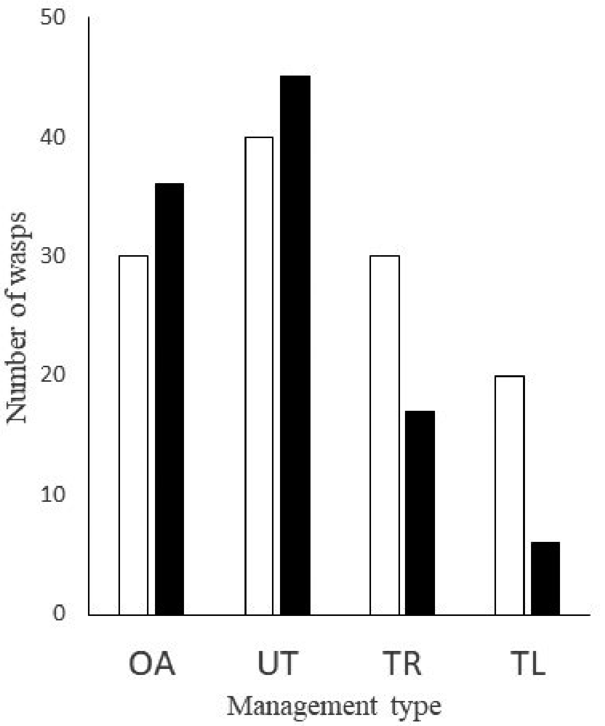

Fig. 1. Total number of individual of *Vespa simillima* (white columns) and *Vespula shidai* (black columns) in 36 stands of four different management types.
OA: old-age stands; UT: unthinned stands; TR: thinned stands deprived of felled trees; TL: thinned stands with felled trees left on stand floor.

The predominance of *V. simillima* and *Vl. shidai* or *Vl. flaviceps* in Malaise trap samples has also been reported in natural deciduous forests in Kanto (Maeto and Makihara 1999, Totok et al. 2002).

V. simillima and the two *Vespula* species have some biological characteristics in common, such as large colony size, long nesting season, and wide ranges of prey (Matsuura and Yamane 1990). Their omnivorous habit may contribute to their dominance in Japanese forests over other vespine species (Totok et al. 2002), especially in coniferous plantations where diversity and abundance of prey may be suboptimal compared with natural forests.

Paper wasps of the genus *Polistes* usually nest on small plants, preferring open and sunny sites to closed and shaded ones (Matsuura et al. 2005). In contrast, *Parapolybia* species nest in more shaded locations, and preferentially nest on the undersides of leaves on the forest floor (Matsuura et al. 2005). This may explain the numerical dominance of *Parapolybia* over *Polistes* species in this study of coniferous plantations.

The management type of stand did not affect the number of species of social wasps, but it influenced the number of individuals of the two predominant species *V. simillima* and *Vl. shidai*. GLM analyses showed that thinned stands (TL in *V. simillima*; TL and TR in *Vl. shidai*) formed different groups from the OA and UT stands. In both species, OA and UT showed larger catches than TR or TL, though the largest catch in Tohoku was obtained in TR stands (Fig. 1).

The results of the GLM analysis do not agree with what is expected from the previous studies which indicate that thinning of Japanese cedar stands increases species richness and/or abundance of various hymenopterans (Maleque et al. 2007a, Taki et al. 2010). One of the possible reasons of the positive effect of thinning may be an increase in the abundance of understory vegetation triggered by thinning, which provides food and/or habitat for insects (Maleque et al. 2007a,b). However, it has also been reported that the extent to which thinning affects insect diversity or abundance varies among taxa. Indeed, Maleque et al. (2007a) showed that vespid wasps in thinned and unthinned stands do not change in abundance, whereas bees and some parasitic wasps respond positively to thinning. The numerical response of vespine wasps to thinning may be weak among insects; landscape structures surrounding the study stands may be important, because vespine workers often make foraging flights over 1 km from their nests (Matsuura and Yamane 1990).

Our results are based on GLMs in which the regions were treated as blocks. This was because we focused our analysis on how thinning of *C. japonica* plantations affects the abundance of social wasps of particular species by setting aside regional effects. However, the three regions showed different distributions in the abundance of wasps among the stands of different management types. It is possible that the effect of management type differed from region to region. We emphasize the need for a more thorough study of plantations in various parts of Japan

On the other hand, the lower catches in thinned stands (TL and TR) than in unthinned (UN) or old-age (OA) stands may be an artifact resulting from a characteristic of the trap. Our Malaise traps were set on the ground surface and captured only those insects that fly low. The thinning of coniferous stands often increases biomass and abundance of understory plants (Maleque et al. 2007a,b); flourishing vegetation on the stand floor could be obstacles for insects flying near the ground, thus making their catches smaller than the actual abundance. Although this hypothesis has not been tested, the characteristics of the trap are an important factor in a biodiversity study, and we must be careful when interpreting results obtained using various types of traps.

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Appendix Table 1. Characteristics of the study stands

Stand#	Region	Age	Area (ha)	Altitude (m)	Management type*	Latitude(N)	Longitude (E)
1	Tohoku	42	5.1	410	TL	38° 54′ 49.27″	140° 24′ 30.39″
2	Tohoku	40	6.9	250	TL	38° 52′ 48.94″	140° 09′ 14.81″
3	Tohoku	36	3.1	300	TL	38° 58′ 54.74″	140° 13′ 58.74″
4	Tohoku	42	2.5	400	TR	38° 59′ 43.96″	140° 18′ 52.43″
5	Tohoku	40	4.7	250	TR	38° 58′ 51.75″	140° 18′ 00.06″
6	Tohoku	42	2.4	240	TR	38° 55′ 59.54″	140° 18′ 10.28″
7	Tohoku	42	8.7	440	UT	38° 59′ 38.22″	140° 18′ 48.46″
8	Tohoku	42	5.5	250	UT	38° 53′ 23.65″	140° 08′ 19.27″
9	Tohoku	44	3.2	360	UT	38° 53′ 07.08″	140° 24′ 12.97″
10	Tohoku	78	43.4	300	OA	38° 59′ 01.22″	140° 20′ 18.61″
11	Tohoku	80	6.8	390	OA	38° 56′ 48.55″	140° 22′ 24.11″
12	Tohoku	90	3.9	350	OA	38° 52′ 23.19″	140° 24′ 30.88″
13	Shikoku	44	8.3	600	TL	33° 31' 51.74"	133° 59' 48.49"
14	Shikoku	44	11.7	500	TL	33° 31' 23.60"	133° 59' 55.90"
15	Shikoku	45	16.4	350	TL	33° 29' 44.33"	134° 05' 13.46"
16	Shikoku	50	85.8	650	TR	33° 38′ 59.86"	134° 08' 25.68"
17	Shikoku	50	52.8	650	TR	33° 36' 21.34"	134° 02' 18.43"
18	Shikoku	50	21.4	200	TR	33° 31' 56.02"	134° 15' 39.47"
19	Shikoku	41	4.3	500	UT	33° 38′ 14.96"	134° 06' 13.52"
20	Shikoku	40	42.0	650	UT	33° 39′ 17.80"	134° 08' 42.60"
21	Shikoku	44	31.8	550	UT	33° 36' 16.54"	134° 05' 25.88"
22	Shikoku	85	21.6	600	OA	33° 39′ 11.80"	134° 05′ 17.20"
23	Shikoku	85	1.4	700	OA	33° 38' 27.80"	134° 05' 16.40"
24	Shikoku	97	67.8	700	OA	33° 32' 11.73"	134° 01 15.28"
25	Kyushu	44	12.8	900	TL	32° 28′ 48.12″	130° 46′ 33.53″
26	Kyushu	45	12.7	850	TL	32° 28′ 23.02″	130° 44′ 30.79″
27	Kyushu	46	9.8	640	TL	32° 09′ 04.24″	130° 42′ 02.48″
28	Kyushu	50	21.1	250	TR	32° 10′ 14.61″	130° 46′ 38.15″
29	Kyushu	40	17.2	510	TR	32° 08′ 09.27″	130° 46′ 25.85″
30	Kyushu	46	11.8	730	TR	32° 06′ 07.51″	130° 45′ 01.41″
31	Kyushu	47	11.9	610	UT	32° 07′ 11.18″	130° 48′ 19.20″
32	Kyushu	51	14.0	650	UT	32° 06′ 00.52″	130° 48′ 22.99″
33	Kyushu	51	7.9	620	UT	32° 04′ 35.53″	130° 42′ 48.37″
34	Kyushu	86	3.4	500	OA	32° 08′ 19.72″	130° 38′ 26.83″
35	Kyushu	92	16.4	700	OA	31° 56′ 45.93″	130° 55′ 25.44″
36	Kyushu	102	5.9	370	OA	31° 49′ 53.68″	131° 12′ 35.63″

*OA: old-age stands; UT: unthinned stands; TR: thinned stands deprived of felled trees; TL: thinned stands with felled trees left on stand floor.

Appendix Table 2. Numbers of social wasps collected with Malaise traps at the study stands

Stand#	*Vespa similllima*		*Vespa ducalis*		*Vespa analis*		*Vespa crabro*		*Vespa mandarinia*		*Vespula shidai*		*Vespula flaviceps*		*Vespula rufa*		*Dolichovespula media*		*Parapolybia crocea*		*Parapolybia varia*		*Polistes nipponensis*		*Polistes rothneyi*		Total
	Q	W	Q	W	Q	W	Q	W	Q	W	Q	W	Q	W	Q	W	Q	W	F	M	F	M	F	M	F	M	
1	1										1	3															5
2		1																									1
3																											0
4	1	2										1				4											8
5	2	2										9				1			1				1				16
6		2										1		1							2						6
7	3	1									1	1															6
8	1																										1
9	2										1					1											4
10		1																									1
11		2									1	1				1	1	3	2								11
12	1	1									3	2					1										8
13	1										1								2								4
14		1										1							6								8
15	2																			1							3
16	5	1																	1								7
17	2										2	3															7
18			1																								1
19	1										2	11							1		2						17
20	5	13									9	8							4		1						40
21	3	1										2			1				1								8
22											1	2							1		2						6
23	1				1							1							1		1						5
24	2	2									2	1															7
25		2		1															4								7
26		1		1															2								4
27	3	8												1					7		4		1				24
28				1				1		1									2				2		1		8
29		2																	8	1			1				12
30	1	10										1							2		1						15
31						1													6						2		9
32																			7								7
33	1	9		1								10		2					3								26
34	1	9				1					6	2							3		1						23
35	1	6									2	12	1						1		2						25
36		3				1													6								10
Total	40	80	1	4	1	3	0	1	0	1	32	72	1	4	1	7	2	3	71	2	16	0	5	0	3	0	350

Q, W, F, and M stand for queen, worker, female (worker or queen), and male, respectively.

スギ人工林においてマレーズトラップで捕獲された社会性カリバチ類

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要旨

森林害虫等の捕食者として働く一方、刺傷事故をもたらす要因でもある社会性カリバチ類（スズメバチ類およびアシナガバチ類）について、東北、四国、九州の 3 地域（各 12 林分）のスギ人工林でマレーズトラップを用いた採集を行った。これら 12 林分は管理方法の異なる 4 カテゴリー（各 3 林分）に分けられた。1）無間伐の老齢林（78-102 年生 ; OA と略記）、2）無間伐林（41 – 51 年生 ; UT）、3）調査から 2-4 年前に切り捨て間伐を行った林分（36 – 50 年生 ; TL）、4）同じく伐出間伐を行った林分（TR）。捕獲された社会性カリバチは合計 13 種（スズメバチ亜科 9 種、アシナガバチ亜科 4 種）、350 個体であった。スズメバチ亜科においてはいずれの地域でもキイロスズメバチ *Vespa simillima* とシダクロスズメバチ *Vespula shidai* が優占的であり、各地域の同亜科総捕獲数のそれぞれ 38-55%、32-52% を占めた。管理方法を固定要因、地域をブロックとした一般化線型モデルにより解析したところ、管理方法は種数には影響を与えなかったが、優占種であるキイロスズメバチとシダクロスズメバチの個体数には影響を与えた。すなわちキイロスズメバチでは OA、UT および TH において個体数が TL よりも大きく、シダクロスズメバチでは UT と OA において、TL と TR よりも個体数が大きかった。過去に報告された昆虫類の多くと異なり、なぜ間伐林で個体数が少なかったのかについて可能な原因を議論した。

キーワード：スズメバチ類、クロスズメバチ類、アシナガバチ類、スギ、人工林、間伐

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