短 報 (Short communication)

Comparison of capture characteristics between Malaise and bait traps for monitoring vespine wasps (Hymenoptera: Vespidae)

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Abstract

The capture quantity and species composition of vespine wasps were compared between Malaise traps (MT) and bait (orange juice mixed with liquor) traps (BT) in six secondary broad-leaved tree stands of different ages in central Japan. MTs and BTs captured a total of 99 vespines of 6 species and 918 of 8, respectively, during the spring (May to June) and fall (August to October) collection periods. BTs captured significantly more vespines than MTs in the youngest stand in the spring and in all six stands during the fall period. Proportions of *Vespa* to *Vespula* specimens were much larger in BTs than in BTs. Overall, BTs is an effective way to compare vespine species diversity and abundance among different sites, if we use them taking into account its low attractiveness to certain groups including *Dolichovespula*.

Key words : social wasps, biodiversity, ecosystem service, *Vespa*, *Vespula*, *Dolichovespula*

1. Introduction

Vespine wasps are important to humans, both in terms of ecosystem services and disservices that they provide. On one hand, they provide us with regulatory services as predators of agricultural or sanitary pest insects (Matsuura and Yamane 1990, Brock et al. 2021) or as facultative pollinators of various plants (Brock et al. 2021) and a provisioning service as food items in countries where they are considered local delicacies (Matsuura 2002, Nonaka 2005). On the other hand, their disservices include serious problems to human health and welfare because of their sting (Edwards 1980, Matsuura and Yamane 1990, Otaki 2005) and predation on honeybees (Matsuura and Sakagami 1973, Monceau et al. 2014). These characteristics of vespines necessitate their monitoring to assess their abundance and species composition in different environments, regions and seasons.

In Japan, two methods are commonly used to monitor vespines: Malaise traps (Totok et al. 2002, Yamauchi and Makino 2010, Makino et al. 2017, Makihara et al. 2020) and bait traps (Makino and Yamashita 1998, Makino and Sayama 2005, Kosaka and Takahata 2015, Sato et al. 2015, Kudô et al. 2021), the latter of which usually use fruit juice and alcohol as bait (attractant). Because Malaise traps are a type of flight interception trap that passively collects insects, they represent an effective means of obtaining data on the temporal and geographic distribution of insects (Darlington and Packer 1988) and their natural flight activities (Muirhead-Thompson 1991). In contrast to Malaise traps, bait traps selectively collect insects of target taxa using appropriate attractants, thus enabling more efficient monitoring than Malaise traps. The decision as to which of these two types of traps to use should take into account how and to what extent any captured specimens will differ in terms of the quantity of the catch and the taxonomic composition.

The studies cited above that used either Malaise traps or bait traps strongly suggest that differences in capture characteristics exist between the two types of traps. However, it is impossible to directly compare each type of trap from the results of these studies, because they were conducted at different sites or regions and they used different sampling protocols (e.g., seasons, durations, or intervals of collection). In this report I compare the catch quantity and species composition of vespines collected in Malaise versus bait traps that were installed in pairs in secondary forest stands of various ages in central Japan.

2. Materials and methods

Pairs of Malaise and bait traps were set in secondary broad-leaved forest in Ogawa (36º56′N, 140º35′E; 580–800 m a.s.l.), Kitaibaraki, Ibaraki Prefecture, central Japan, in 2002. The study sites comprised six stands of secondary broad-leaved forest, which were aged 4, 12, 24, 51, 71 and 128 years after clear cutting (Taki et al. 2013). The dominant tree species were *Quercus serrata*, *Q. mongolica* and *Fagus crenata* (Taki et al. 2013). The age of a stand can have a major impact on the assemblage of insects that inhabit it, including aculeate

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wasps (Makino et al. 2021). Therefore, the simultaneous monitoring of sites that differed widely in age was expected to more accurately reflect the capture characteristics of the two types of traps than if they were set at sites with similar conditions. Five Malaise traps (hereafter abbreviated as MTs) and five bait traps (BTs) were installed at each of the six sites (Fig. 1). Townes-type MTs (Golden Owl Publishers; 180 cm long, 120 cm wide and 200 cm high) were set up on the forest floor. The BTs, which were made of clear plastic beverage bottles (30 cm high, 10 cm wide, 2000 ml volume, with one 3 × 3 cm window at the upper part: Makino and Sayama 2005), were tied onto tree trunks with string, except in the 4-year-old stand. In this youngest stand, the BTs were tied to poles (approximately 10 mm in diameter and 200 cm in height) placed in the ground because there were no trees large enough on which to fix the traps. All BTs were attached approximately 1.5 m above the ground. In each site, five MTs were placed in a row, with an approximate interval of 10 m between each trap, and the BTs were installed in the same way. The rows of MTs and BTs were separated at least by 10 m to minimize any interactions between them. Plastic collection bottles were attached to the top of the MTs; these bottles contained 70% ethanol mixed with an equal amount of propylene glycol to act as a preservative. The bait used in the BTs was a 1:1 mixture of orange juice and a clear liquor made from sweet potato (alcohol content: 25%), which was used in previous studies (e.g. Makino and Yamashita 1998, Makino and Sayama 2005, Kosaka and Takahata 2015). The collection of vespines in the traps was carried out during two time periods, spring and fall, which are the principal flight periods of overwintered queens and workers, respectively, in central Japan. The study sites were visited three times during the spring period (between May 9 and June 19 for the MTs and between May 8 and June 20 for the BTs) and four times during the fall period (between August 15 and October 8 for the MTs and between August 16 and October 15 for the BTs), with intervals of about two weeks (12–16 days) between the visits. At each visit, any insects captured in the traps were collected and the preservative in the MTs and the bait in the BTs were renewed. In the laboratory, vespine wasps were sorted from other captured insects and identified to species, caste and sex. The dates of visits differed between the MTs and BTs by 1 to 6 days, so the catches from individual traps were pooled to give the number of vespines obtained during the whole of the spring or the fall collection period.

Capture characteristics of MTs and BTs were compared in terms of the number and the species assemblage of collected specimens. The numbers of vespines collected were compared between MTs and BTs for each of the six study sites separately for the two (spring and fall) collection periods. Correlations of the number of collected vespines between MTs and BTs were examined to see if the catches by the two traps changed similarly among the sites. For these analyses, the catches of all species were pooled for each site. The data were not normally distributed, therefore non-parametric methods were used for the statistical analyses, i.e., Mann-Whitney *U* test to test the difference between two groups and Kendall's tau to detect correlations. All statistical analyses were carried out using R version 4.1.1 (R Core Team 2021). To compare species assemblages of vespines collected by MTs and BTs, a non-metric multidimensional scaling (NMDS) ordination was made for the spring and fall collections separately, as well as the

Fig. 1. Malaise traps (left) and a bait trap (right) used to collect vespine wasps. Five pairs of Malaise and bait traps were installed at each of six deciduous broad-leaved stands.

pooled data of the two seasons. In this analysis, the species with more than three individuals were used. The ordination was made using the package "vegan" (Oksanen, et al. 2019) for R, with Bray-Curtis distances used as dissimilarity measures.

3. Results

A total of 1,017 vespine wasps of 10 species belonging to three genera were caught at the six sites during the study period (Table 1): 918 in the BTs and 99 by the MTs. Of the ten species collected, four (*Vespa simillima, V. mandarinia, Vespula shidai* and *Vl. flaviceps*) were caught by both MTs and BTs. The remaining six species were captured only by MTs (*Vl. rufa* and *Dolichovespula media*) or only by BTs (*V. analis, V. crabro, V. ducalis* and *V. dybowskii*). *D. media* was a singleton and *V. dybowskii* a doubleton even when pooling all samples.

During the spring collection period, the difference in catch between BTs and MTs was not significant (p>0.05, Mann–Whitney *U* test) except in the youngest (4-year-old) site (p=0.027) (Fig. 2). During the fall collection period, however, the difference in catch between BTs and MTs was significant at all sites (0.011<p<0.015). In the spring, all wasps captured in both types of traps were overwintered queens. By contrast, in the fall, all wasps collected by the MTs and the majority (92%) of those collected by the BTs were workers, with the remainder of the BT specimens comprising males (5%) and possible new queens (or “gynes”) (3%). Despite the differences in the quantity of catch, BTs and MTs produced similar results among the sites in terms of relative abundance: the number of vespines captured in the BTs correlated with that captured by the MTs among all sites during both the spring and fall seasons (spring: Kendall’s tau=0.786, p=0.032; fall: 0.828, p=0.022).

The NMDS analyses showed that the species assemblages of the collected vespines were different between MTs and BTs (Fig. 3). In the spring collections, the ordination did not represent the difference very well, as indicated by the stress value >0.2 (Clarke 1993). However, in the fall samples and in the pooled samples of the two seasons, the plots showed good ordinations of the different assemblages between the two trapping methods (stress < 0.2). The plots also showed that the species of *Vespa* and those of *Vespula*, on average, appeared more frequently in BT and MT samples than vice versa, respectively (Table 1). Almost all (spring: 98%; fall: 95%; pooled: 95%) specimens captured by BTs comprised the *Vespa* species, of which *V. simillima* was dominant (spring: 69%; fall: 53%; pooled: 55%). *Vespula* species accounted for only small parts (spring: 2%; fall: 5%; pooled: 5%) in the BT collections. Unlike BTs, MTs caught relatively more *Vespula* than *Vespa* specimens: the former occupied 60% (spring), 73% (fall), and 68% (pooled) of the total catch, with the latter accounting for the rest except for a single *D. media* in the spring. In the MT samples, *Vl. shidai* was dominant among the *Vespula* species (spring: 82%; fall: 77%; pooled: 79%), and almost all *Vespa* specimens were of *V. simillima* except for a single *V. mandarinia* in the spring.

4. Discussion

The BTs generally captured a larger number of vespines per trap than the MTs (Table 1). During the spring, this difference

Table 1. Numbers of vespines collected by Malaise and bait traps in the spring (early May–late June) and fall (late August–early/mid October) collection period, each at six sites of different stand ages in deciduous broad-leaved forests in central Japan. Figures under the label "Spring" and "Fall" show the stand ages of the sites. Total numbers of individuals are given for each season ("total"), as well as for the two seasons combined ("All").

Trap type/species	Spring							Fall							All
	4	12	24	51	71	128	total	4	12	24	51	71	128	total	
Malaise trap															
Vespa simillima Smith	10	2	1	1	0	2	16	7	5	2	0	0	0	14	30
Vespa mandarinia Smith	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Vespula shidai Ishikawa et al.	1	1	1	10	3	7	23	8	0	5	7	5	5	30	53
Vespula flaviceps Smith	0	1	2	0	1	0	4	2	1	1	2	0	0	6	10
Vespula rufa (L.)	0	0	0	0	1	0	1	0	0	0	0	3	0	3	4
Dolichovespula media (Retzius)	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Bait trap															
Vespa simillima Smith	50	6	2	9	4	10	81	53	11	88	126	74	51	403	484
Vespa mandarinia Smith	6	4	2	3	1	0	16	126	41	6	25	0	24	222	238
Vespa analis Fabricius	14	0	0	0	1	0	15	14	1	10	3	1	3	32	47
Vespa crabro L.	2	0	0	0	0	0	2	4	0	2	2	0	0	8	10
Vespa ducalis Smith	3	0	0	0	0	0	3	41	21	23	3	0	1	89	92
Vespa dybowskii André	0	0	0	0	0	0	0	0	0	1	0	1	0	2	2
Vespula shidai Ishikawa et al.	0	0	0	0	0	0	0	4	4	8	9	10	2	37	37
Vespula flaviceps Smith	1	0	0	0	1	0	2	0	2	4	0	0	0	6	8

was significant only at the youngest site, whereas during the fall BTs captured significantly larger numbers of specimens than the MTs at all sites. Although the duration of the capture period (from installation to removal of the traps) was a little longer for the BTs than the MTs, by 2 and 5 days in the spring and fall, respectively, these differences were less than 10% of the total duration. This seems too small to be the reason for the far larger numbers of captures by BTs compared with the MTs at the sites where significant differences were detected between them (Fig. 2).

The high performance (large catch) of BTs in collecting vespines is to be expected because the bait, which contains fruit juice, has been demonstrated to effectively attract vespines by emitting odors similar to those of fermented tree sap (Ono 1997). In the spring period, BTs collected significantly more individuals (overwintered queens) than MTs only at the youngest, 4-year-old stand (Fig. 2). Although the reason was not clear, overwintered queens, especially of *Vespa*, may more frequently forage carbohydrate foods in open, sunlit places than shaded ones as compared with workers.

Unlike BTs, MTs collect only those insects that happen to collide with them, thus they provide a more accurate reflection of the density of flying insects (Darlington and Packer 1988). It should be noted, however, that the number of trapped vespines was correlated between MTs and BTs among the sites both during the spring and the fall. This indicates that BTs can be used to gain an understanding of the relative abundance of all vespine species as a whole.

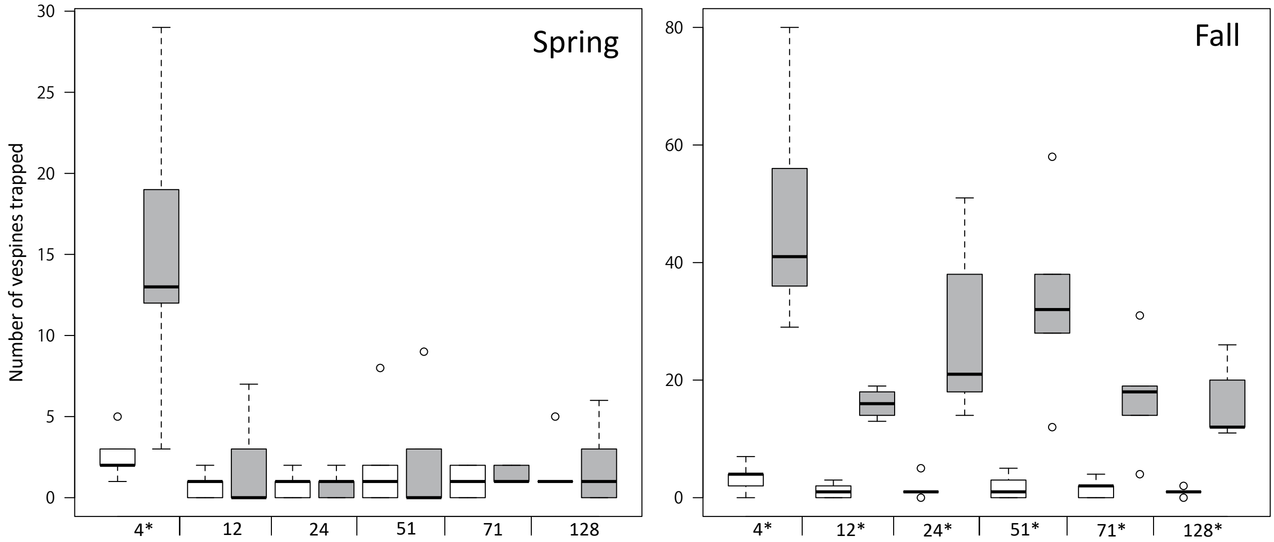

Fig. 2. Box plots showing the numbers of vespines collected by five Malaise (open columns) and five bait (gray columns) traps during the spring (left) and fall (right) seasons at six monitoring sites in broad-leaved forest stands of different ages, which are shown on the y-axis. Stand ages with an asterisk (*) show that the numbers captured significantly differed between Malaise and bait traps (0.011<p<0.015, Mann–Whitney *U* test). Within each box, median, first quartile, and third quartile are represented by a thick solid line, upper line, and lower line of the box, respectively. Vertical dotted lines represent the most extreme values within 1.5 interquartile range of the first and third quartile. Small open circles are outliers.

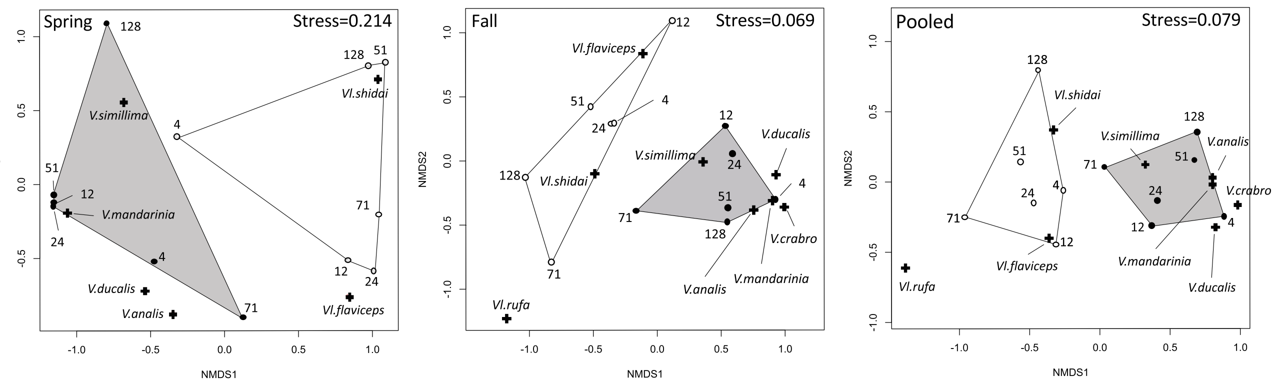

Fig. 3. NMDS plots of vespine samples collected with Malaise (open circles and open convex) and bait (solid circles and grey convex) traps in the spring, fall, and pooled collections of both seasons. Figures near the circles show stand ages of the sites. Crosses show the species represented by weighted average of the site scores. Their generic names are abbreviated as "*V* ."for "*Vespa*" and "*Vl.*" for "*Vespula.*"

The species assemblages of collected vespines differed greatly between the MTs and the BTs. The MTs collected relatively more *Vespula* than *Vespa* specimens than BTs (Table 1, Fig. 3). The main species of *Vespula* collected, *Vl. shidai*, principally nests underground (Matsuura and Yamane 1990). In addition, *V. simillima*, which occupied almost all *Vespa* specimens trapped by MTs, preferentially initiate nests in closed spaces including underground cavities (Matsuura and Yamane 1990). It is suggested that these species may fly near the ground surface more frequently and thus might be more prone to being captured by MTs compared with aerial nesters such as *D. media* and *V. analis*. The dominance of *Vl. shidai* and *V. simillima* in MT samples have also been reported by other studies made in forested areas in various parts of Japan (Totok et al. 2002, Yamauchi and Makino 2010, Makino et al. 2017). It should be noted, however, that Makihara et al. (2020) collected as many *D. media* as the subterranean nester *Vl. shidai* with MTs in forests and their surroundings in Fukushima, northern Japan. Therefore, it is possible that population densities and habitat conditions are also responsible for the capture of *D. media*.

The relatively smaller proportion of *Vespula* species captured by BTs than MTs may be due to two possible reasons. First, the most important carbohydrate source of *Vespula* is not tree sap but homopteran honeydew both for queens and workers (Matsuura and Yamane 1990). Therefore, as long as there is abundant honeydew in the field, wasps of the genus are possibly less frequently attracted than those of *Vespa* to the bait that emits an odor similar to fermented tree sap. Second, the fall sampling period may have been ended too early (October 15) to capture *Vespula* workers. Makino and Sayama (2005) showed in their study using BTs (from April or May through November) that virtually all *Vl. shidai* and *Vl. flaviceps* specimens were collected after late October. This may be because in the late fall, homopteran honeydew is possibly scarce, which makes BTs relatively more attractive. In fact, in the present study almost all *Vespula* workers captured in BTs were collected during the latter half of the fall period (between September 30 and October 15). Therefore, if the BT collections had been made after late October, it is possible that more *Vespula* specimens could have been collected. Makino and Sayama (2005) also reported very scarce occurrences of specimens of *D. media* and *Vl. rufa* captured in BTs in Hokkaido, where these taxa are commonly distributed. These species, as in *Vespula*, may not be captured by BTs even if they are present, because they show lower preferences for tree sap than *Vespa*, and their nesting seasons are much shorter than those of *Vl. shidai* or *Vl. flaviceps* (Matsuura and Yamane, 1990). In fact, Makihara et al. (2021) captured *D. media* and *Vl. rufa* in MTs but not in BTs, despite the two traps being used simultaneously.

To conclude, the BT is a useful way to monitor vespine species diversity and abundance. BTs can usually capture much larger numbers of vespine individuals, and equal to larger numbers of species, than MTs, and thus represent a useful monitoring approach. However, the potential weakness of BTs is that they may not attractive to a few taxa, such as *Dolichovespula*, and some species of *Vespula* including *Vl. rufa*.

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スズメバチ類の捕獲特性におけるマレーズトラップと誘引トラップの比較

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要 旨

関東地方の樹齢の異なる 6 つの広葉樹二次林において、マレーズトラップ（MT）とベイトトラップ（BT）（餌はオレンジジュースと焼酎の混合）とでスズメバチ亜科の捕獲数と種組成を比較した。春季（5 月～ 6 月）と秋季（8 月～ 10 月）に、MT は合計 6 種 3 属 99 個体、BT は 8 種 2 属 918 個体を捕獲した。BT は春季には最も若い林分で、また秋季には 6 林分すべてにおいて、MT よりも多くの個体を捕獲した。BT では MT に比してクロスズメバチ属よりスズメバチ属の捕獲比率が高かった。全体として BT は、ホオナガスズメバチ属など特定のグループに対する誘引性が低いことを考慮して使用すれば、スズメバチ亜科の多様性と現存量を比較する有効な方法であると言える。

キーワード : 社会性狩りバチ、生物多様性、生態系サービス、スズメバチ属、クロスズメバチ属、ホオナガスズメバチ属

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