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SHORT COMMUNICATION

WEATHER-RELATED DIFFERENCES IN ATTRACTIVENESS OF PROTEIN FOODS TO *VESPULA* WASPS

Summary: Low acceptance of protein baits by common *(Vespula vulgaris)* and German *(V. germanica)* wasps (Hymenoptera: Vespidae) occurred after rain in honeydew beech forest. This corresponded with a sharp decrease in the proportion of natural protein in the diet of *V. vulgaris* and *V. germanica,* and a reduction in the concentration of carbohydrate-rich honeydew in the crops of foraging wasps carrying liquid. The reduction of protein foraging most likely results from a change in the efficiency of foraging wasps at gathering high energy foods such as honeydew after rain, because rain reduces honeydew availability. Workers may therefore take longer to meet their own energy requirements before they can forage for protein to feed developing larvae.

Key words: wasps; *Vespula vulgaris; Vespula germanica;* diet; rain; honeydew; carbohydrate; protein; poisoning.

Introduction

Poison baiting has been used to reduce local populations of common *(Vespula vulgaris* (L.)) and German *(V. germanica* (F.)) wasps from picnic, camping and logging areas (Spurr, 1989; *pers. comm.).* However, Thomas *et al*. (1989) were unable to eliminate sufficient common wasps for long enough to complete an experimental test of the impacts of wasps on insects and birds. Their failure appeared to be due to low acceptance of the protein baits. Spurr (1989; *pers. comm.)* also described variation in bait take between trials, and earlier poisoning protocols using fish baits laced with Mirex poison (Perrott, 1975) had highly variable success (Walton and Reid, 1976; Akre *et al.,* 1981).

In order to reduce such variation in bait acceptance the mechanisms causing changes in wasp foraging patterns need to be understood. This paper describes the influence of recent rainfall on the number of common wasps accumulating on protein baits in a honeydew beech forest *(Nothofagus* spp.) in the South Island. Honeydew consists of drops of sugary exudate that accumulate on the ends of the anal filaments of native scale insects *(Ultracoelostoma assimile* (M.); see Crozier, 1981; Grant and Beggs, 1989; Morales, HilI and Walker, 1988).

Interpretation of the bait acceptance data was assisted by a subsidiary investigation into the influence of rain on the type of natural food being transported to wasp nests by foraging common and German wasps.

Methods

Study areas

Wasp baiting was conducted at Pelorus Bridge Scenic Reserve, 25 km east of Nelson. Wasp forager loads were studied at Spooners Scenic Reserve, 35 km southwest of Nelson, and at Tiropahi, 28 km south of Westport on the West Coast of the South Island.

Spooners is a patch of honeydew-infested beech forest amidst pine plantation forest, and has been described by Gaze and Clout (1983). The Pelorus Bridge and Tiropahi sites are on the margins of much more extensive honeydew beech forests, and have been described by Sandlant and Moller (1989) and Harris, Thomas and Moller (1991), respectively. The wasps at Pelorus Bridge and Spooners were all *V. vulgaris*. *V. germanica* and *V. vulgaris* colonies were located at Tiropahi in 1989. In 1990, all of the 30 nests located in the Tiropahi area belonged to *V. vulgaris,* and only 3.4% of workers collected while foraging were *V. germanica* (Harris *et al.,* 1991). Therefore, eight *V. germanica* colonies were moved into the site to enable species comparisons to be made (see Harris 1991, for details).

Baiting

Five baiting trials were conducted at Pelorus Bridge between January and April 1989. From 22 to 75 bait stations made from 130 mm x 230 mm polystyrene trays were placed on the ground, at 15-30 m intervals along a transect through the forest. Each tray was baited with 30 g portions of cat food consisting of sardines in aspic jelly ("Wonder cat" brand, packed by Pataya Food Industries Ltd, Samutsakorn, Thailand). Bait stations were revisited 1-7 times in the 4 hours after being established. The number of wasps feeding on bait at the moment of arrival at each bait station was recorded. If wasps had removed all bait from a tray no counts were made.

Marked wasp nests in the area were visited during each bait trial and the number of wasps leaving each colony in one minute counted. This "traffic rate" provides an index of numbers of wasps flying in the area during each trial (Malham *et al*. 1991).

Rainfall was recorded daily on open land 300 m from the study site.

Wasp forager loads

In 1989, wasps returning to nests at Tiropahi and Spooners were intercepted with an entrance trap (see Harris, 1989), and any load being carried was removed and identified (Harris, 1991). Prey foragers were defined as those carrying an external load of animal matter; wasps excluded from the forager category carried wood pulp or had no external load. Samples were collected on 23 days between 2 February and 7 May 1989. Sampling days were split into wet (n=10) and dry (n=13) based on the presence or absence of rain in the 24 hours prior to sampling.

At the Tiropahi site in 1990 individual foragers were gassed with CO_2, and had their crop contents regurgitated by applying pressure, using forceps, to the underside of the abdomen. If the wasp regurgitated any liquid, it was collected in a 1 mm diameter capillary tube, and its volume determined. The sugar concentration of the liquid was determined with a hand held refractometer (Grant and Beggs, 1989). Carbohydrate foragers were classified as those wasps with a crop containing a clear sugary liquid. Foragers returning to common and German nests were intercepted on five days between 20 March and 10 April 1990. A 2.5 - 3 hour period was spent sampling each species on each day. Sampling days were split into wet (n=2) and dry (n=3) based on the presence or absence of rain in the 24 hours prior to sampling.

Results

Bait trials

Numbers of wasps per bait in the five trials ranged from 0.59 to 10.81 (Table 1). Despite such wide fluctuations in the numbers of wasps at baits, traffic rates of wasps at nests were very similar on all sampling days (Table 1). The lowest daily mean number of wasps on baits (8 February) differed significantly from the next lowest mean (13 March; $t = 32.1$, d.f. = 438, $p < 0.001$). The February trial was conducted after 3 days of rainfall (95 mm in total) and we suggest that this influenced the number of wasps on baits. However, it is clearly not the only factor involved as almost 5-fold differences in catches were recorded on the other days.

Differences in numbers of wasps per bait between days did not result from differences in the numbers of times each bait was visited because there was little change (apart from initial build-up in numbers) in the abundance of wasps while bait remained, and visits to trays by observers were about equally spaced throughout the 4 hour observational period after bait was put out.

Wasp forager loads

The proportion of foragers carrying prey after wet and dry days varied between species and site (Table 2). However, at both sites wasps collected more prey after fine weather than after wet weather.

No differences were found in the volume of crop fluid carried by returning carbohydrate foragers between wet and dry days, or between species (Table 3). However, the concentration of sugar in crop fluid of returning foragers was lower after wet days for both species (Table 3). The decrease in concentration was greater for *V. vulgaris* than for *V. germanica*.

Table 1. *Numbers of wasps (mean ± 95% C.I.) on cat-food baits and numbers leaving wasp nests per minute at Pelorus Bridge. Bait stations with all bait removed were excluded from the analysis. Rainfall in the three days before each bait trial is also shown.*

Date	Number of bait stations	Wasps per bait	Number of counts made	Wasps per minute	Number of nests counted	3-day Rainfall (mm)
31 Jan 89	75	10.81 ± 3.05	48	37±5.25	56	0
8 Feb 89	60	0.59 ± 0.19	261	24±5.25	45	95
2 Mar 89	60	5.93 ± 1.06	84	25 ±3.70	58	1
13 Mar 89	60	2.33 ± 0.47	179	32 ±5.02	42	0
10 Apr 89	22	6.44 ± 1.18	140	23±4.19	40	1

Table 2. *The percentage of vespulid worker wasps returning to nests at Spooners Range Scenic Reserve and Tiropahi (from* 23 *sampling days between* 2 *February and* 7 *May* 1989) *which carried prey in wet (10 days) and dry weather* (13 *days*). "*Wet*" *days were those in which some rain was recorded in the* 24 *hours prior to sampling*. *The number of wasps sampled is in parentheses*.

	Percentage of wasps carrying prey		
Weather	Spooners	Tiropahi	
	V. vulgaris	*V. vulgaris*	*V.germanica*
Wet days	2.59 (541)	5.26 (380)	1.81 (554)
Dry days	18.46 (2172)	14.91 (966)	24.95 (461)
All days	15.14 (2713)	11.33 (1346)	12.31 (10515)
Comparison	X^2	*d.f.*	*P*
Species difference at Tiropahi			
WET	4.49	1	0.034
DRY	15.98	1	<0.001
Site difference for *V. vulgaris*			
WET	8.67	1	0.003
DRY	34.15	1	<0.001
Weather difference			
Spooners *V. vulgaris*	85.92	1	<0.001
Tiropahi *V. vulgaris*	14.14	1	<0.001
Tiropahi *V.germanica*	124.78	1	<0.001

Table 3. *The volume and concentration of crop liquid in German and common wasps foraging for carbohydrate after wet and dry weather at Tiropahi in 1990. ANOVAs were carried out on log-transformed data. Wet weather was defined as days in which any rain fell in the* 24 *h prior to sampling*. *The number of wasps sampled is in parentheses*.

Species	Weather	Mean volume ± 95% C.I. (_l)	Mean concentration ± 95% C.I. (g $100g^{-1}$)
V. germanica	Dry	14.8 ± 1.1 (61)	20.3 ± 1.1 (61)
	Wet	16.7 ± 1.2 (43)	14.0 ± 1.1 (43)
V. vulgaris	Dry	14.7 ± 1.1 (55)	19.0 ± 1.1 (55)
	Wet	14.7 ± 1.1 (55)	11.8 ± 1.1 (55)
ANOVA table for crop volume			
Source of variation	d.f.	F-ratio	*P*
Species	1	1.00	0.3163
Weather	1	0.84	0.3585
Species X weather	1	0.78	0.3785
ANOVA table for concentration			
Species	1	7.13	0.0076
Weather	1	95.78	<0.0001
Species X weather	1	1.41	0.2352

Discussion

After rain there is a dramatic drop in protein feeding by wasps (Table 3), and consequently in their interest in protein baits put out to poison them. The drop in protein feeding is not simply a reduction in activity (traffic from nests), as during bait trials activity remained similar whether bait-take was low or high, and marked reductions have only been recorded during very heavy rain (Spradbery, 1973).

The main prey of wasps in honeydew beech forest are spiders and insects (Harris, 1991). It is unlikely that less invertebrate food was available after rain, causing a reduction in protein brought to nests, because the number of wasps on baits was lowest after rain at Pelorus Bridge. The reverse would be predicted if protein foods other than baits were hard to find. In addition, fewer wasps are seen foraging for prey directly after rain *(pers. obs.)*.

Energy demands of a colony may be increased due to rain, increasing carbohydrate foraging at the expense of protein collection. Reductions in traffic rates (the number of wasps entering and leaving a nest per unit time) have been recorded in heavy rain (Spradbery, 1973), so this could be a contributing factor. Protein foraging, however, remains depressed long after rain has stopped and traffic rates have returned to normal levels; therefore another factor is involved.

The principal reason for the reduction in protein foraging appears to relate to the ability of foraging wasps to gather high energy foods after rain. Honeydew drops are diluted and washed onto the ground or tree trunk by rain. This triggers a change from feeding directly on honeydew drops to a lapping mode of feeding (Moller and Tilley, 1989), and thus an increase in time spent gathering honeydew at each tree *(unpubl. data)*. Our results show that while foragers returned with the same volume of fluid, the sugar concentration, and consequently energy content, of their load was much reduced in wet compared with dry conditions. This may result in the collection of high energy foods like honeydew becoming an immediate priority for the sustenance of the colony, rather than the collection of protein, which is required for larval growth. Variation in honeydew quality and concentration, along with variation in wasp density may explain some of the variation in bait acceptance on days when no rain was recorded at Pelorus during baiting trials (Table 1). We are now investigating the changes that occur in the honeydew resource and the response of the wasps to these changes.

Deployment of poison bait stations is expensive, time-consuming and potentially dangerous to humans and non-target animals. Fish and meat baits quickly decay and lose their attractiveness to wasps once exposed to air and sunlight *(pers. obs.)*. Consequently, baiting should be avoided altogether (in honeydew-rich beech forests at least) until a small scale pre-poisoning trial after rain shows a resurgence of interest in protein foods by wasps. This will indicate the maximal level of bait attractiveness that can be achieved at that site, during that season, and so maximise chances of success.

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