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PREY DIETS AND POPULATION DENSITIES OF THE WASPS *VESPULA VULGARIS* AND *V. GERMANICA* IN SCRUBLAND-PASTURE

Summary: Prey collected by *Vespula vulgaris* and *V. germanica* were sampled by intercepting foragers returning to nests at two sites in scrubland-pasture near Hamilton. About 12% of returning foragers carried animal prey and 5% carried wood pulp. The remaining 83% carried no external load. The most common prey item for both species was Diptera, followed by Lepidoptera and Araneae (spiders).

Even in similar habitats the two species collected different prey, with *V. germanica* collecting more Diptera and *V. vulgaris* more Lepidoptera. The prey changed slightly over time at both sites.

V. germanica and *V. vulgaris* collected an estimated 1800 g and 600 g of prey nest^{-1} season^{-1} respectively. The wasps collected an estimated 75 000 prey loads ha-l season-l at Mystery Creek and 12 000 at Ruakura. This represents biomasses of 50 and 470 g ha^{-1}, respectively, which are at least an order of magnitude lower than estimates of prey biomass for honeydew beech forest in parts of the South Island. The distribution of wasp nests was patchy however, and the biomass of prey collected exceeded 10 kg ha^{-1} in some places.

Keywords: *Vespula vulgaris; V. germanica;* wasps; diet; biomass; seasonality.

Introduction

The introduced social wasps *Vespula vulgaris* (L.) and *V. germanica* (F.) can reach estimated peak densities of 10 000 ha^{-1} in honeydew beech forests of the South Island (Thomas, C.D., *et al.,* 1990). At such levels, wasps may be having a considerable impact on the beech forest system by consuming honeydew (Moller and Tilley, 1989; Beggs and Wilson, 1991), and protein in the form of invertebrate prey (Harris, 1991).

Food intake has not been studied in non-honeydew habitats in New Zealand, and apart from occasional records of wasps preying on invertebrates (e.g., Thomas, C.R. 1960; Kleinpaste, 1980; Thomas, B., 1987), the relative importance of prey items, the biomass consumed, and the likely impact of that predation are all unknown.

In this paper, the prey collected by vespulid wasps is described for two rural sites around Hamilton city, New Zealand. The German wasp, *V. germanica,* became established in the Waikato region in the 1940s (Thomas, C.R., 1960), but the common wasp, *V. vulgaris,* is a more recent arrival, with only one nest found before 1988 (M. Reid, *pers. comm.).* Estimates of wasp density and prey consumption in scrubland-pasture are calculated and compared with those in honeydew beech forest.

Study areas

The Mystery Creek site is approximately 100 ha of farmland 11 km south-south-east of Hamilton city, on the banks of the Waikato river (37°47', 175°20'). It consists of flat pasture dissected by two steep banks, and a number of drains and ornamental ponds. The steep banks provide a variety of habitats, such as regenerating native forest, young and mature pine plantations *(Pinus radiata* (D. Don.)), blackberry *(Rubusfruticosus* (L.) agg.), pasture grasses, and mixtures of mature native and exotic ornamental trees.

The Ruakura study site is 633 ha of intensively farmed pasture surrounding a landscaped research campus on the eastern edge of Hamilton city (37°52.5', 175°21.5'). Scattered across the farmland are a number of drains and shelter belts of South American pampas *(Cortaderia* spp.) and poplars *(Populus* spp.).

Methods

Intercepting returning foragers

An entrance trap was used to catch returning foragers (Fig. 1). The large-diameter outer tube was secured in place at the nest entrance after dark using black polythene and soil. This tube caused minimal disturbance to the colonies, and foragers did not establish alternative entrances. Four nests at Mystery Creek and five at Ruakura were trapped by collecting samples in an inner collecting tube (Fig. 1) over 32 days between 16 January and 19 May 1992. After 1 - 10 min (shorter periods as nests got larger) the inner tube was removed and trapped foragers were asphyxiated with CO_2, Prey fragments were removed for identification. Some additional prey samples were gathered by collecting returning wasp foragers with a hand net.

Wasp density

All accessible areas of each site, which were sub-divided into blocks based on fences and habitat variation, were searched for nests early in the wasp season (Dec-Feb), and again at the height of wasp abundance (Mar-Apr), to give and estimate of density (nests ha^{-1}).

As a measure of changes in worker wasp abundance through the wasp season, the traffic rate, i.e., the number of wasps entering or leaving a nest per minute, was monitored on each nest from the date it was first located until nest traffic declined to below 5 wasps min-1 at the end of the autumn (May). The traffic rate of foraging workers entering or leaving nests can be used to calculate the total number of workers in a nest (Malham *et al.,* 1991).

For each nest the number of foragers was estimated on 3 to 16 days over the season by averaging from three to five 1-minute counts of the traffic entering or leaving. Curves estimating the number of foragers entering each nest throughout the season were fitted using a Bayesian smoothing technique (Steinberg, 1984; Upsdell, 1985; McCullagh and Neider, 1989). From the individual curves the overall pattern of wasp activity between 1 January and 1 July 1992 was also estimated. An approximate standard error was obtained by taking the difference in areas under the upper and lower confidence curves.

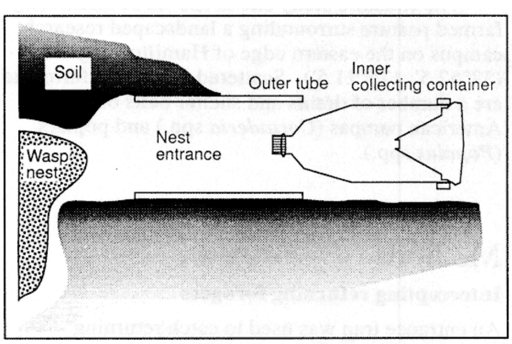

Figure 1; *Trap used to sample returning wasp foragers.*

The area under the curve, multiplied by the daylight hours (calculated for each month from Ruakura weather data - range 9 - 14 hours) gave an estimate of the total foraging trips per nest. The overall mean and error for each species were estimated from the individual nest data using the ANOVA results.

The density of workers per hectare was estimated from equations used by Thomas, C.D. *et al.* (1990) and the traffic rate of nests at peak calculated from the Bayesian curves. The regression equations were developed for *V. vulgaris* in honeydew beech forest of the South Island but should give a reasonable approximation due to the similar seasonal patterns of nest development (Harris, *pers. obs.).*

Number of Adults (at peak) =
481.42 + 37.187 x Traffic rate at peak

Number of workers (at peak) =
Number of adults x Proportion that are workers

The proportion of adults at peak that were workers (0.561) was determined from detailed examination of 21 *V. vulgaris* nests (Thomas, C.D., *et al.,* 1990).

Prey consumption

At Ruakura a random sub-sample of prey collected by each species was weighed on the day of collection for each of 8 days between 29 January and 13 March 1992 to provide an estimate of prey biomass. Estimates of the number of prey loads brought into nests and the fresh weight biomass of prey consumed per hectare were then obtained using the same equations as Harris (1991).

Results

Wasp diet

A total of 7225 foragers were caught in the entrance traps at the two sites, of which 838 (11.6%) carried prey, 5.4% carried wood pulp, and 83% carried no external load. An additional 20 prey items were collected from wasps caught in a hand net. Of the 852 prey items collected overall, 95 % were identified to at least order and used in the subsequent analysis (Table 1).

Table 1: *Summary of prey loads taken from* Vespula *foragers at Ruakura and Mystery Creek in* 1992. *For two nests the total number of wasps caught is unknown as a net was used to sample some prey items. A detailed list of prey taxa is available from RJH on request.*

Site	Ruakura				Mystery Creek	
Species	*V. vulgaris*		*V. germanica*		*V. vulgaris*	*V. germanica*
Habitat	Pampas	Garden	Pampas	Farm	Pasture-Scrub	Pasture-Scrub
No. of nests sampled	2	1	1	1	2	2
Sampling days	15	10	20	6	8	9
Wasps caught	1304	1547	>1084	631	1466	>1193
Prey items collected	174	164	172	101	130	117
Identified prey	172	153	166	101	127	115
Prey Order						
Araneae	15	34	24	7	18	9
Diptera'	86	67	113	64	59	70
Hemiptera	8	3	7	1	13	5
Hymenoptera	4	1	8	2	3	2
Lepidoptera (adult)	2	1	2	10	1	5
(larvae)	50	45	6	15	28	13
Other	7	2	6	2	5	11

The relative occurrence of prey types in the diet of *V. vulgaris* and *V. germanica* at Ruakura and Mystery Creek was similar (Fig. 2 a,b), but there were differences in the relative occurrence of dipteran families between sites (Fig. 3 a,b). At Mystery Creek, prey type did *not* differ significantly between nests of the same wasp species, so data were combined for nests of the same species. However, the representation of prey types differed significantly between the two wasp species (Fig. 2a; $X^2 = 8.04$, d.f. = 3, $P < 0.05$). Although the relative occurrence of the common prey types was the same, with Diptera being the most abundant prey component for both wasps, *V. germanica* took a greater percentage of Diptera and lower percentage of Araneae, Hemiptera, and Lepidoptera than *V. vulgaris*. There were also significant differences in the relative proportion of dipteran families. *V. germanica* foragers returned with greater numbers of Syrphidae, Calliphoridae, and Sarcophagidae; while *V. vulgaris* had greater numbers of Tipulidae and Sepsidae (Fig. 3a; $X^2 = 19.70$, d.f. = 4, $P < 0.001$).

Minor changes in diet during the season were evident for both wasp species, with the percentage of Diptera increasing and Araneae decreasing from February through April (Fig. 4a: *V. vulgaris,* $X^2 = 11.38$, d.f. = 6, $P = 0.077$; Fig. 4b: *V. germanica,* $X^2 = 14.76$, d.f. = 4, $P = 0.052$).

At Ruakura, the pattern was complicated by habitat variation. However, three nests (two *V. vulgaris* and one *V. germanica)* were located along the same pampas hedge. The prey types carried by foragers from the two *V. vulgaris* nests were not significantly different, so data were combined. Diptera were again the most abundant component for both wasp species, and *V. germanica* brought in more Diptera, and *V. vulgaris* more Lepidoptera ($X^2 = 30.64$, d.f. = 4, $P < 0.001$). The composition of dipteran families did *not* differ significantly between the two species.

The *V. germanica* nest in the bank of a ditch differed from the *V. germanica* nest in the pampas hedge in having greater numbers of Lepidoptera (40% of which were adults) in the diet. The relative importance of dipteran families was also significantly different ($X^2 = 21.49$, d.f. = 4, $P < 0.001$). The *V. vulgaris* nest in a landscaped garden within the Ruakura campus differed from the two nests in the pampas hedge in that Araneae were more prominent in the diet and the importance of dipteran families was again significantly different ($X^2 = 9.62$, d.f. = 3, $P = 0.022$).

For all but one nest at Ruakura the proportion of different prey types altered significantly through the season, with Diptera generally increasing and Lepidoptera larvae decreasing.

Wasp densities and traffic rates

At Ruakura, nest density for *V. vulgaris* and *V. germanica* combined was estimated at 0.06 nests ha-l (Table 2). The distribution of nests varied, with highest densities around the landscaped part of the campus (0.31 - 1.25 nests ha^{-1}). At Mystery Creek nest density was higher (0.33 nests ha^{-1}). Again nests were unevenly distributed, with the highest density being 7.86 nests ha^{-1} on a hillside containing blackberry, pine plantation and logging debris.

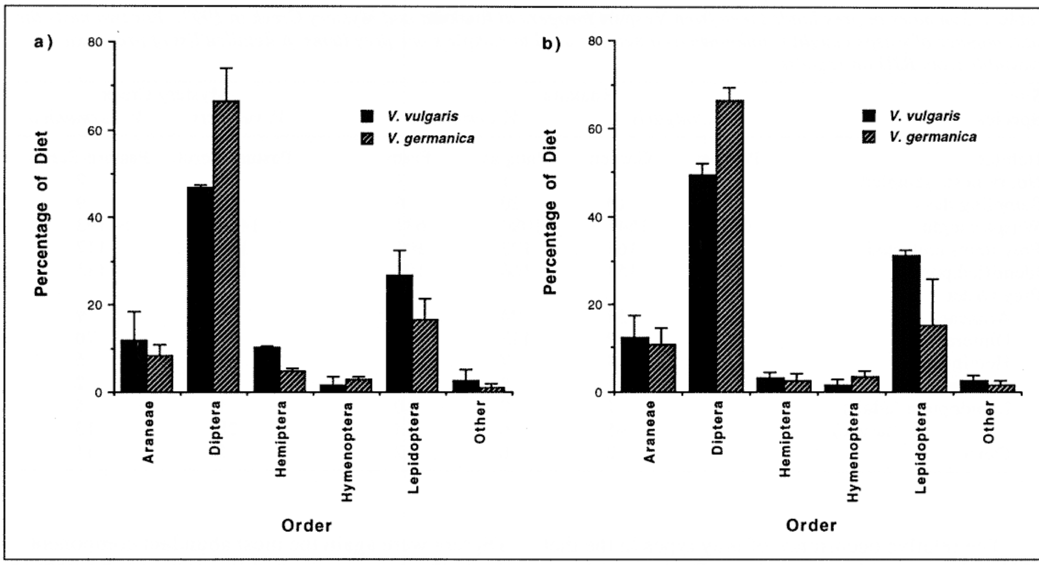

Figure 2: *Differences in prey loads carried by foragers* of Vespula germanica *and* V. vulgaris *at (a) Mystery Creek and (b) Ruakura in* 1992. *Mean + S.E.*

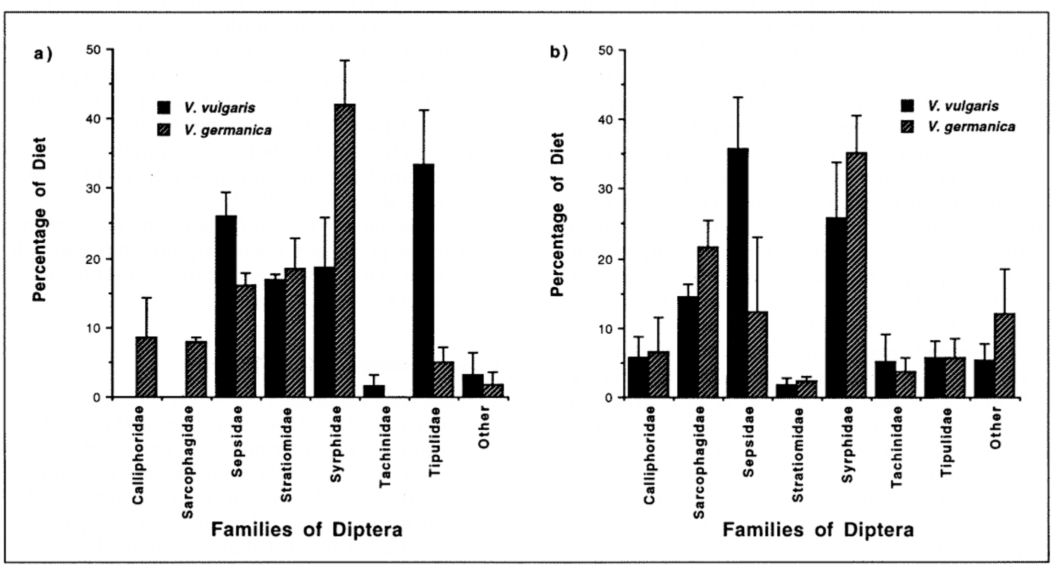

Figure 3: *Differences in families of Diptera collected by foragers* of Vespula germanica *and* V. vulgaris *at (a) Mystery Creek and (b) Ruakura in* 1992. *Mean + S.E.*

Table 2: *Wasp density and prey collection by* V. vulgaris *(Vv) and* V. germanica *(Vg) colonies in two rural Hamilton sites during the* 1991-92 *wasp season.*

Site	Block	Area (ha)	No of Nests Vv	No of Nests Vg	Density (nest ha^{-1})	Worker density at peak (workers ha^{-1})	Prey carrying foragers (103 ha^{-1} $season^{-1}$) mean ± SE	Biomass of prey taken (kg ha^{-1} $season^{-1}$) mean ± SE
Ruakura	1	16.31	4	1	0.31	321	64.9 ± 12.6	0.36 ± 0.06
	2	5.3	6	0	1.13	1170	231.1 ± 43.3	0.70 ± 0.17
	3	8.0	9	1	1.25	1305	260.8 ± 49.6	0.92 ± 0.24
	4	185.3	3	2	0.03	28	5.9 ± 0.7	0.03 ± 0.01
	5	49.3	0	0	0.00	0	0	0
	6	289.4	4	1	0.02	18	3.7 ± 0.7	0.01 ± 0.004
	Across site	553.5	26	5	0.06	58	11.8 ± 2.3	0.05±0.01
Mystery Creek	1	1.4	3	8	7.86	8113	1741 ± 361.2	11.28 ± 2.78
	2	4.0	1	6	1.75	1852	403.5 ± 85.0	2.83 ± 0.71
	3	9.7	6	5	1.13	1194	248.9 ± 49.9	1.31 ± 0.32
	4	72.8	0	1	0.01	15	3.3 ± 0.7	0.02 ± 0.01
	Across site	89.9	10	20	0.33	354	75.4 ± 15.5	0.47 ± 0.12

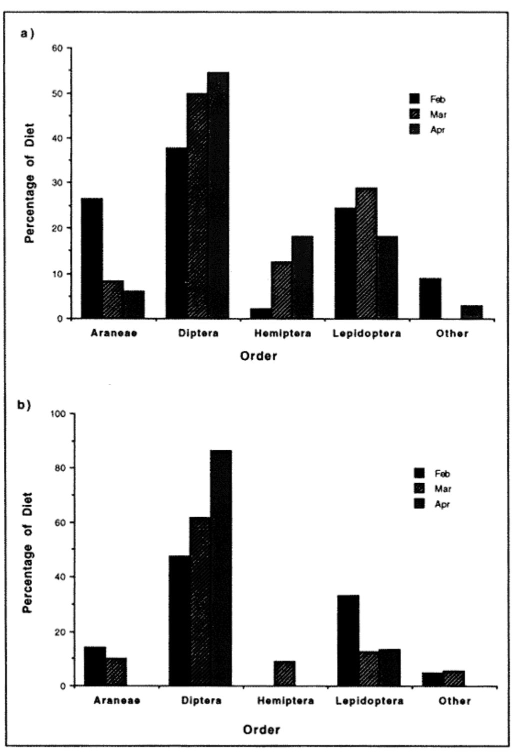

Figure 4: *Seasonal changes in the prey collected by (a)* Vespula vulgaris *and (b)* V. germanica *colonies at Mystery Creek in* 1992.

The activity of nests through the season was estimated for each species from the traffic rates of nests (Fig. 5). Although the two species showed similar patterns, *V. germanica* maintained greater foraging activity later in the season (May - June) as two nests survived into winter. The average traffic rate at peak was similar for the two species (38.4 for *V. germanica* and 36.8 for *V. vulgaris).* Estimates of worker densities at peak season were 354 ha^{-1} for Mystery Creek and 58 ha^{-1} for Ruakura (Table 2). High localised densities of up to 8113 workers ha^{-1} were obtained in the block with the highest nest density.

From the estimates of seasonal activity it was calculated that there was an average of 2.04 (S.E. = 0.44) million worker foraging trips from each *V. germanica* nest per season, and 1.76 (S.E. = 0.33) million worker foraging trips from each *V. vulgaris* nest per season.

Prey biomass

V. germanica foragers returned to sampled nests with mean prey loads 2.5 times heavier than those of *V. vulgaris (V. germanica,* mean = 7.6 mg, S.E. = 1.3, n = 56; *V. vulgaris,* mean = 3.01, S.E. = 0.5, n = 103; t = 3.92, d.f. = 156, $P < 0.001$). Load weights for taxonomically similar prey samples did not differ statistically between wasp species, but the weight of taxonomically different prey samples did (ANOVA; F = 3.62, d.f. = 14,130, $P < 0.001$). *V. germanica* brought back the heaviest prey items, but foragers of both species most frequently

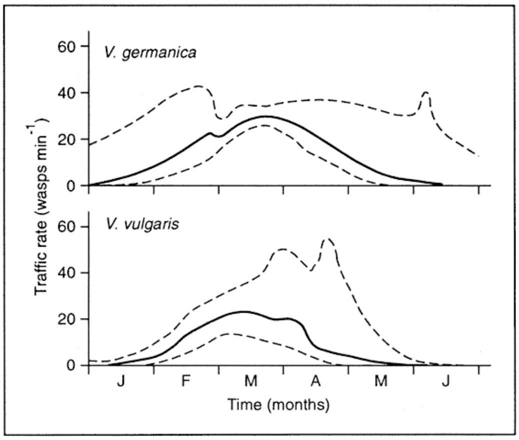

Figure 5: *Changes in seasonal traffic rate for (a)* Vespula germanica *and (b)* V. vulgaris *from 1 January to 1 July 1992. The solid line represents the mean traffic rate, the dotted lines upper and lower confidence bands for standard errors.*

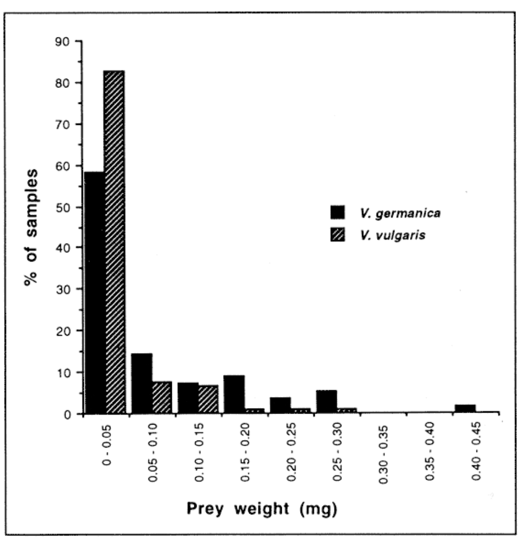

Figure 6: *Weight of prey loads for* Vespula vulgaris *and* V. germanica *at Ruakura.*

returned with prey items weighing less than 0.05 mg (Fig. 6).

Total forager visits and the proportion of foragers carrying prey can be used to estimate prey biomass and the total number of prey items collected by the total wasp population. *V. germanica* and *V. vulgaris* collected an estimated 1800 g and 600 g of prey nest^{-1} season^{-1} respectively. For Ruakura an estimated II 800 prey-carrying foragers ha^{-1} season^{-1} returned to nests of *V. vulgaris* and *V. germanica* combined (Table 2). This converts to an estimated 50 g of prey ha^{-1} season^{-1} being taken into nests when averaged over the whole site (Table 2). For the block of highest wasp density the estimate of prey biomass was 920 g ha^{-1} season^{-1}. For Mystery Creek an estimated 75400 prey-carrying foragers ha^{-1} season^{-1} returned to nests of *V. vulgaris* and *V. germanica* combined. This converted to 470 g of prey ha^{-1} season^{-1}. For the block of highest nest density the prey biomass was an estimated 11.28 kg ha^{-1} season^{-1}.

Discussion

The arthropod prey of wasps in semi-urban scrub and pasture habitats of the Hamilton region is broadly similar to that recorded in honeydew beech forest of the South Island, where Diptera, Lepidoptera, and spiders were common foods (Harris, 1991). In beech forest habitat a greater range of insect orders in the diet was recorded, which probably reflects a greater species' diversity in that habitat.

Prey differences between the two wasp species living sympatrically in scrubland - pasture habitats probably reflect different patterns of microhabitat use, as seen in honeydew beech forest where *V. germanica* foraged for protein more commonly amongst the forest litter, and *V. vulgaris* foraged more on shrubs and tree saplings (Harris, Thomas and Moller, 1991). In this study, the differences in prey between nests of the same species in different habitats probably reflect differences in local prey abundance.

Overall estimates of wasp prey biomass for the Hamilton sites are an order of magnitude lower than those estimated in the beech forests of Nelson (8.1 kg ha^{-1} season^{-1}) and West Coast (1.4 kg ha^{-1} season^{-1}) (Harris, 1991). However, the high nest density blocks in each Hamilton study site had estimates of prey biomass that are comparable to those from honeydew beech forest. Estimates per individual nest for the Hamilton sites were high compared to beech forest, due, in part, to the preponderance of *V. germanica* whose foragers returned to nests with heavier loads of prey. *V. vulgaris* has almost completely replaced *V. germanica* in beech forests (Harris, 1992).

Nest densities around Hamilton were low (< 1 nest ha^{-1}) compared with beech forest around Nelson and West Coast, where densities ranged from 1 to 32.9 nests ha^{-1} (Barlow, Moller and Beggs, 1992). As only sparse information is available on nest densities in habitats other than honeydew beech forest it is not possible to say whether densities recorded in this study are unusually low. A survey of golf courses around the North Island gave estimates of density ranging from 0 to 0.14 nests ha^{-1} (Harris, *unpubl. data),* but these are minimal estimates as the areas were not searched systematically. A Department of Conservation monitoring program found that wasp abundance, measured using baited traps, was higher in honeydew beech forests than in other habitats (Moller *et al.,* 1990).

V. germanica nests occasionally overwinter in New Zealand (Thomas, C.R. 1960; Plunkett *et al.,* 1989) and two nests located in this study did so. This contributed to the higher overall traffic estimate for *V. germanica* than for *V. vulgaris* because their traffic rate did not decline to zero in autumn. The winter consumption of invertebrates would add to the seasonal prey biomass estimates in this region. Overwintering nests become very large in their second season, which leads to relatively high localised wasp densities and subsequent heavy prey consumption.

The potential impact of wasp foraging in scrubland-pasture is unknown because nothing is known about prey densities in this habitat. Overall forager densities were low at the two sites. The patchy distribution of nests may mean that some localised pressure may be experienced by prey populations, as most foragers fly only 50 - 400 m from the nest (see Edwards, 1980, for review). Future studies involving manipulations of wasp density and monitoring of prey populations are required to quantify the impact of wasp predation on invertebrates in a range of habitats.

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