

No evidence for establishment of the wasp parasitoid, *Sphecophaga vesparum burra* (Cresson) (Hymenoptera: Ichneumonidae) at two sites in New Zealand

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Abstract *Sphecophaga vesparum burra* (Cresson) (Hymenoptera: Ichneumonidae) has been released at seven sites in New Zealand as a biological control agent for wasps (*Vespula* spp.). Between 1996 and 1998, more than 35 000 overwintering cocoons were released nationwide, more than half of them at two South Island sites: Binsler Track in Arthur's Pass National Park (13 200 cocoons) and Tennyson Inlet in the Marlborough Sounds (13 660 cocoons). Monitoring at these two climatically and altitudinally disparate sites revealed that over 5000 adult parasitoids emerged at each site over the 4 years. More than 300 wasp nests were dug and inspected for attack by *S. v. burra*, but there was no evidence of establishment.

Keywords *Vespula*; Vespidae; biological control

INTRODUCTION

Two species of *Vespula* wasps, *V. vulgaris* (L.) and *V. germanica* (F.) (Hymenoptera: Vespidae) are highly successful invaders in New Zealand, particularly in beech (*Nothofagus*) forests with abundant honeydew-producing scale insects (Beggs 2001). Wasps reach very high densities in about 1 million ha of this native beech forest, (Thomas et al. 1990) and are a conservation threat to native fauna (Beggs

2001). It is estimated that wasp abundance needs to be reduced by 80–90% to mitigate the impact on some native invertebrate species in beech forest (Toft & Rees 1998; Beggs & Rees 1999). *Vespula* spp. are also pests of several primary industries. They are also major social pests because they are a public health threat, disrupt people's enjoyment of the outdoors, and the operation of some schools (Beggs 2000).

Biological control of invasive invertebrates has seldom been attempted to conserve native biodiversity (Van Driesche & Hoddle 2000). This New Zealand attempt at using *Sphecophaga vesparum burra* (Cresson) is unusual because it was undertaken primarily to reduce the impact of *Vespula* wasps on native invertebrates, native birds, and disruption of ecosystem processes (Beggs 2001).

Biological control is considered the only option that could achieve viable long-term suppression of wasp densities in native ecosystems because of the generally isolated and difficult terrain and the widespread nature of the problem. Two subspecies of the vespid wasp parasitoid *S. vesparum* (Curtis) have been introduced. The first was *S. v. vesparum*, obtained from *V. vulgaris* and *Dolichovespula saxonica* (F.) colonies in Switzerland, Germany, and Austria during 1980 and 1981. Progeny from these importations has been released throughout much of New Zealand since early 1985 (Donovan & Read 1987; Beggs et al. 1996). *S. v. vesparum* has established in at least two sites in the South Island (Moller et al. 1991; Beggs et al. 1996). It has a moderate dispersal ability (1–1.5 km yr⁻¹), but a low local rate of increase and/or carrying capacity relative to the host's abundance (Barlow et al. 1998). At best, it is calculated to suppress wasp density by up to 25% and at worst, to have a negligible effect (Toft et al. 1999).

The second subspecies, *S. v. burra*, was first obtained from *V. atropilosa* (Sladen) colonies in Washington State during 1979, and 798 cocoons were imported. Rearing this subspecies proved difficult, and by late 1982 the population in New Zealand was extinct (Donovan & Read 1987). Another attempt at introduction was made, with at least 560 cocoons

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collected from *V. vulgaris*, *D. maculata* (L.) and *D. arenaria* (F.) colonies in Washington State and northern Idaho between 1991 and 1995 (Harris & Read 1999; B. Donovan pers. comm.).

The two subspecies are morphologically distinct (Berry et al. 1997), but have similar life histories:

In spring, *S. vesparum* females enter wasp nests and lay eggs on developing wasp pupae. The resulting parasitoid larvae feed on the wasp pupae, killing them in a few days. Pupating parasitoid larvae form one of three types of cocoon (Donovan 1991), depending on the nutrition the larva has received (Harris & Rose 1999). Two cocoon types give rise to adults within the same season—thin-walled white cocoons produce brachypterous adults, and thin-walled yellow cocoons produce apterous adults. The third type are tough yellow (hereafter called overwintering) cocoons that produce winged females or males that may spend up to 4 years in a dormant state before emerging. In late autumn and early winter, most wasp nests die out and the nest material generally decomposes rapidly, except for the overwintering parasitoid cocoons that will remain in the cavity that housed the nest until their emergence 1–4 years later.

The primary reason for releasing a different subspecies of *Sphecophaga* was that genetic variability might affect the success of a biocontrol agent. Two commonly listed critical attributes are adaptability to local climatic conditions and the ability to avoid host defence (Roush 1990). It was thought that *S. v. burra* could be more synchronous with its host since it is adapted to a different climate. Furthermore, the Barlow et al. (1996) model predicts that very small differences in some characteristics, such as the emergence patterns from overwintering cocoons, could result in improved control.

This paper summarises the attempt to use *S. v. burra* to control wasps.

METHODS

Releases

Two release methods were used.

Cocoon releases

Overwintering cocoons (each cocoon contains a single parasitoid) were placed in soil inside release boxes at seven sites during winter (Table 1). The release boxes had wire-mesh-covered exit holes to prevent rodents eating cocoons. Boxes were placed in shady sites away from public view and revisited annually from 1996 to 1999 to record the number of emerged parasitoids. The number of cocoons recorded as released is a minimum; when cocoons were joined to form a double, they were sometimes inadvertently counted as one.

Emergence and establishment was monitored only at Binsler Track and Tennyson Inlet. Binsler Track is a high elevation site (540–600 m a.s.l.) on the margin of Arthur's Pass National Park and high-country pasture. Beech trees with honeydew are abundant. The site traditionally has high wasp densities; indeed it had the highest abundance of wasps of 68 sites in the Department of Conservation's nationwide wasp-monitoring network in 1990 (Beggs et al. 1990). Both sites had earlier releases of *S. v. vesparum*, so had been checked in 1996 to confirm that it had not established (Harris & Read 1999).

Release boxes were placed in forest up to a kilometre on either side of the Tennyson Inlet settlement. This is a low elevation site (<30 m a.s.l.) that has a climate similar to Pelorus Bridge where

Table 1 Sites where *Sphecophaga vesparum burra* was released.

Site	Inoculation release	Year of release	No. of cocoons	Grid reference (NZMS 260)	Organisation responsible
Binsler Track	Yes	1996, 97, 98	13 200	L34 131999	Landcare Research
Tennyson Inlet	Yes	1996, 97, 98	13 660	P27 740093	Landcare Research
Sharplin Falls	Yes	1997	1000	K36 823299	Staveley Community
Waitakere Ranges	No	1996, 97	5490	Q11 465785	Auckland Regional Council
Murchison	No	1997	1000	M29 606334 M29 606349	Tasman District Council
Athenree Gorge	No	1998	300	T13 674116	Environment Bay of Plenty
Mayor Island	No	1998	700	U13 970289	Environment Bay of Plenty

S. v. vesparum has established. Beech trees with honeydew are present throughout the site.

Nest inoculation

Wasp comb containing white *S. v. burra* cocoons was inserted directly into 82 nests in the field (nest inoculation). Inoculations were carried out during summer at Binsler Track, Tennyson Inlet, and Sharplin Falls (Table 1). The exact number of white cocoons in each piece of comb before inoculation was determined for 11 of the nests inoculated at Binsler Track. Nests were left until autumn. It was initially intended to dig only a subsample of nests and leave the remainder at the release sites to contribute to the pool of cocoons from which establishment could begin, but the nature of the results led to all the nests being dug and inspected for evidence of parasitism.

Table 2 Number of nests checked for establishment of *Sphecophaga vesparum burra* and probability of detecting it if present in a given year.

Site	Year	No. nests checked	Probability of detection
Binsler Track	1997	19	0.49
	1998	41	0.77
	2001	95	0.97
Tennyson Inlet	1997	0	0.00
	1998	63	0.89
	2001	102	0.97

Wasp nest density

Three people searching a permanently marked strip plot estimated the density of wasp nests. The plot was 10 m × 1300 m at Tennyson Inlet, and 10 m × 1500 m at Binsler Track. Counts were done in February or March each year.

Checking for establishment of parasitoid

All cocoons in release boxes were removed in May 2000. Therefore, any *S. v. burra* detected from 2001 onwards would have originated from field-reared cocoons. This would signify that the parasitoid had established. Altogether, 320 nests within close proximity of the release boxes (<2 km) were dug up in March 1997, 1998, and 2001 (Table 2). Nests were checked for signs of parasitism by visual inspection of each layer of comb. The probability of detecting establishment (*P*) was calculated using the following equation. We assumed the proportion of nests parasitised to be 0.035; the lowest rate of parasitism recorded at Pelorus Bridge (Beggs et al. 1996).

$$P = 1 - x^y$$

where

x = 1 – proportion of nests parasitised,

y = the number of nests checked.

RESULTS

Cocoon releases

S. v. burra was released at three North Island sites and four South Island sites (Fig. 1). About 35 350 cocoons were released nationwide, of which most

Table 3 Release and emergence of *Sphecophaga vesparum burra* at Binsler Track and Tennyson Inlet (cumulative totals in bold).

Release site	Year	Cocoons released	Cumulative no. of cocoons	Cumulative no. of adults emerged	Wasp density (nests ha ⁻¹)
Binsler track	1995	0	0	0	24.0
	1996	2600	2600	91	10.6
	1997	2300	4900	529	14.7
	1998	8300	13 200	3934	9.3
	1999	0	13 200	5089	12.0
Tennyson Inlet	1995	0	0	0	3.9
	1996	1597	1597	50	0.8
	1997	2508	4205	1160	4.6
	1998	8056	13 660	5835	8.5
	1999	0	13 660	6855	6.2

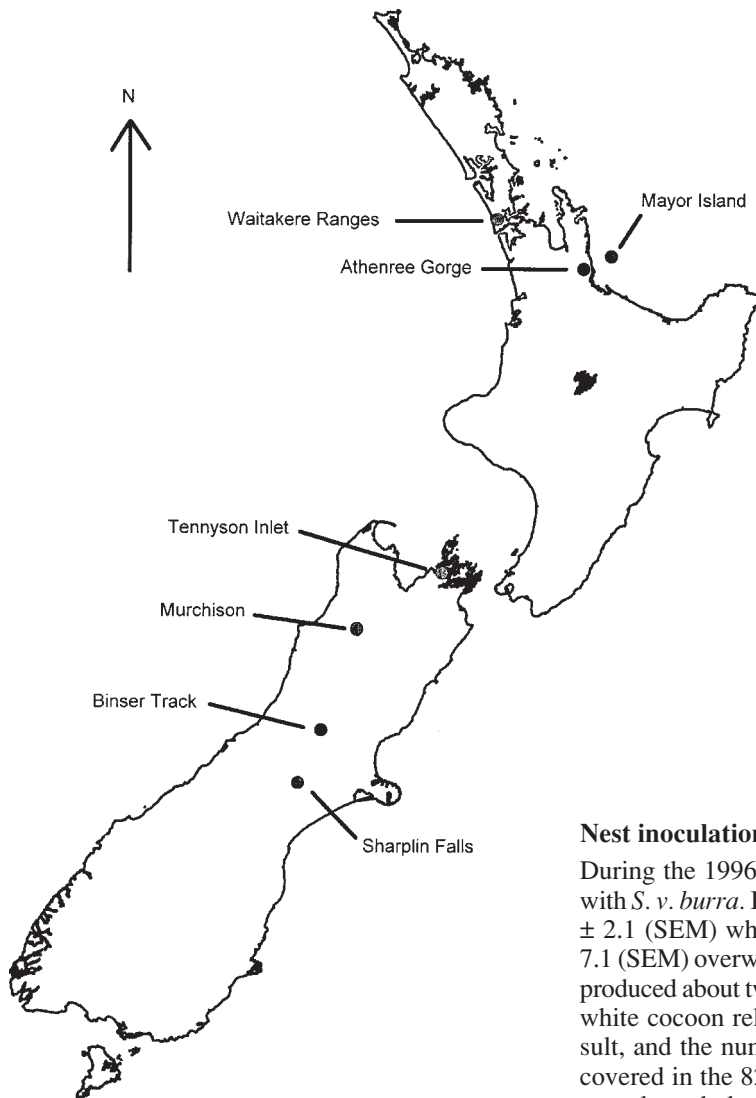


Fig. 1 Location of sites where releases of *Sphecophaga vesparum burra* have been made.

were placed at two sites (Table 1). At Binsler Track and Tennyson Inlet, 26 860 cocoons were released over three seasons (Table 3). Adults emerged from 5089 (39%) cocoons at Binsler Track, and from 6855 (50%) cocoons at Tennyson Inlet. In all years, more parasitoids emerged from the Tennyson Inlet site than at Binsler Track (Fig. 2), possibly due to the warmer lowland climate. In any one year, between 50 and 4675 parasitoids emerged per site (mean = 1493; SEM = 589).

Nest inoculation

During the 1996/97 season we inoculated 82 nests with *S. v. burra*. In 11 of these nests we released 14.9 ± 2.1 (SEM) white cocoons, and recovered 26.6 ± 7.1 (SEM) overwintering cocoons. Thus, inoculation produced about two overwintering cocoons for every white cocoon released. Extrapolating from this result, and the number of overwintering cocoons recovered in the 82 nests (Table 4), we estimate that we released about 19 white cocoons per nest, i.e., 1555 white cocoons in total.

From the results of inoculation trials using *S. v. vesparum* in the 1995/96 season, we expected more than 40% of the inoculated nests to be successfully attacked and large numbers of cocoons produced by the end of the season. However, this was not the case. Only nine inoculated nests (11%) had parasitoid cocoons found in comb other than the inoculated material (Table 4). These nine nests produced only 134 new overwintering cocoons in total and all but 12 of these cocoons were at Binsler Track. The inoculated nests were dug up in autumn, but it is possible they contributed a small number of adult parasitoids to the wild during that year because winged adults may have emerged earlier.

Fig. 2 Cumulative number of parasitoids emerging from overwintering cocoons placed in release boxes at Binser Track and Tennyson Inlet, relative to the density of wasp nests. The horizontal line (11.2 nests ha⁻¹) represents the average nest density measured at seven other sites for 10 years (Beggs 2001).

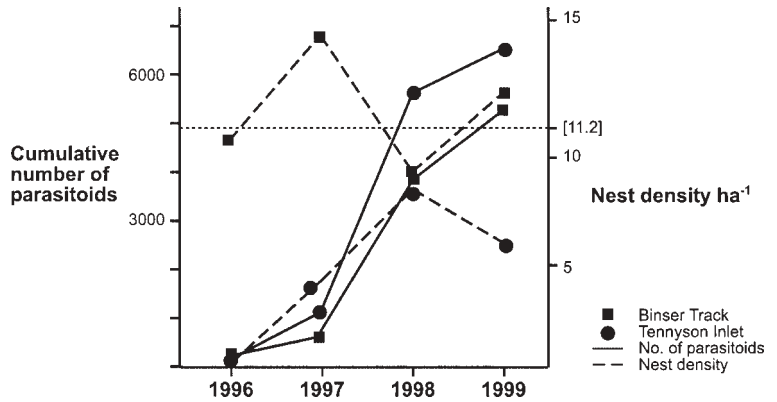


Table 4 Success of *Sphecofphaga vesparum burra* parasitoids from inoculated comb in attacking the rest of the nest. Mean \pm SEM is given. *7.9 \pm 6.3 chewed overwintering cocoons also found. Rodents probably chewed these (see Toft et al. 1999).

Site	No. cocoons from which parasitoids had emerged	Mean no. intact overwintering cocoons recovered from inoculated comb	No. nests successfully attacked per no. nests inoculated	Mean no. overwintering cocoons produced in successfully attacked nests
Binser Track	27	30.4 \pm 3.9	8/35	15.3 \pm 11.5
Tennyson Inlet	16	52.7 \pm 9.9*	0/19	—
Sharplin Falls A	6	4.8 \pm 1.6	0/21	—
Sharplin Falls B	0	38.7 \pm 14.0	1/7	12

Wasp nest density

The density of *Vespa* nests varied from year to year, but was consistently higher at Binser Track (mean = 14.1 nests ha⁻¹, SEM = 2.6) than at Tennyson Inlet (mean = 4.8 nests ha⁻¹, SEM = 1.3; Table 3, Fig. 2). Nest density was particularly high (24.0 nests ha⁻¹) at Binser Track in 1995, and particularly low (0.8 nests ha⁻¹) at Tennyson Inlet in 1996.

Establishment of parasitoid

No parasitised nests, other than those directly inoculated, have been recovered from either release site, despite inspection of 310 nests. Enough nests were dug at both sites in 2001 to have a 97% chance of detecting the parasitoid if it had established (Table 2).

DISCUSSION

There is no evidence that *S. v. burra* has established in New Zealand, despite the release of large numbers

of cocoons at Binser Track (13 200) and Tennyson Inlet (13 660). The year when most parasitoids emerged (1998) coincided with a year when both sites had a moderate wasp density (Fig. 2), compared with a mean density of 11.2 (SE = 0.3) nests ha⁻¹ measured in seven beech forest sites over 10 years (Beggs 2001).

Of the seven release sites, we suggest that *S. v. burra* had the best chance of establishing at the two sites checked, because the number of cocoons released at these sites was greater by an order of magnitude than at the other release sites (Table 1). The other five sites cover a broad range of environmental conditions. It is possible that *S. v. burra* has established in at least one of these other sites, but, to date, no wasp nests from these sites have been inspected for *S. v. burra*.

In contrast, *S. v. vesparum* was released at many more sites throughout New Zealand (Beggs et al. 1996). At 26 sites, enough nests were inspected to give >80% probability that the parasitoid would be detected. However, at only three of these sites were

more than 800 cocoons released in areas with high wasp density, and it was at two of these sites that establishment had occurred (Beggs et al. 1996). *S. v. vesparum* was not found at any of the other sites.

Emergence of adults from cocoons is variable, so the number of cocoons released represents the maximum number of live insects released. In this study, adults emerged from fewer than 50% of released cocoons.

Biological control literature is divided over whether it is a better strategy to release a large number of individuals in a few places (e.g., Beirne 1975; Cameron et al. 1993; Grevstad 1999), or a small number of individuals in many places (e.g., Campbell 1976; Memmott et al. 1998) to increase the overall probability of establishment. The optimum establishment strategy is likely to vary with species and environment. Since the limited data we had on a close relative of *S. v. burra* indicated that a large number of founder parasitoids released at sites with high wasp nest density increased the probability of establishment (Beggs et al. 1996), and because our resources for monitoring were limited, we adopted the first strategy. Large numbers of *S. v. burra* cocoons were released over three consecutive seasons, and adult parasitoids emerged over 4 years. The average number of parasitoids emerging per year (1493) was close to the threshold of 1000 insects/release suggested by Hopper & Rousch (1993) to ensure establishment of introduced parasitoids.

While most *S. v. burra* were released as overwintering cocoons in release boxes, we also tried inoculating the parasitoid directly into wasp nests. The latter proved to be a difficult and time-consuming process, with limited success (Harris & Read 1999). In contrast, earlier trials using this technique with *S. v. vesparum* were more successful (Harris & Read 1999). This difference may indicate behavioural and/or physiological differences between the two subspecies.

It is not unusual for biocontrol agents to fail to establish in the field. Fewer than 50% of biocontrol agents released against introduced insects establish successfully (Stiling 1990). We do not know why *S. v. vesparum* failed to establish. Wasps attack intruders in their colonies, including parasitoids, perhaps reducing the probability of a biocontrol agent establishing. The ability of a biocontrol agent to avoid host defence is a key attribute for its success (Roush 1990).

There have now been two attempts to introduce *S. v. burra* into New Zealand, and it is likely both have failed (Donovan & Read 1987; this study).

We do not intend to attempt a third time because of the cost of such an undertaking and the uncertainty of the parasitoid impact on wasp populations, if it did establish.

Given the lack of establishment success with *S. v. burra*, and the failure of *S. v. vesparum* to reduce wasp populations significantly (Beggs & Harris 2000), alternative control options need to be considered. Other potential invertebrate biological control agents do not look promising (Beggs & Harris 2000). Poison baiting has proved to be successful in achieving substantial reductions in wasp abundance, but only in relatively small areas (Beggs et al. 1998; Harris & Etheridge 2001). There is still a need to develop control tools that can be applied at a much larger scale.

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