Food plants and foraging distances for the native bee Lasioglossum sordidum in Christchurch Botanic Gardens

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Abstract: With concerns about declines in pollinating bee species worldwide, there is renewed interest in solitary native bee species and their role in pollination services. We studied the foraging preferences and foraging distances of *Lasioglossum sordidum* (Halictidae), New Zealand's smallest solitary bee, in urban Christchurch. *Lasioglossum sordidum* were abundant within the Christchurch Botanic Gardens. Pollen samples taken from 40 bees at each of two nest sites were identified using a pollen reference collection from the sites. Bees were collecting pollen from both native and exotic plants. In total, pollen from 23 different plant taxa was found, but 96% came from five taxa: Asteraceae (65%), *Hebe* spp. (16%), *Aesculus* spp. (8%), *Yucca baccata* (3%) and *Taraxacum officinale* (3%). Individual bees usually specialised in a few pollen types, with 74% of bees having >90% of a single pollen type and a mean of 2.6 pollen types per bee. The minimum flight distances to the nearest sources of each pollen type were typically 70–250 m. These easily overlooked bees may be assisting more in general pollination services given the diversity of plant taxa from which the bees were collecting pollen, the variation from bee to bee in the plant taxa collected, and the sometimes considerable minimum foraging distances exhibited.

Keywords: *Aesculus*; Asteraceae; flower constancy; Halictidae; *Hebe*; pollination

Introduction

Pollination by animals is important for seed production in many plants and has a strong positive effect on seed production in a range of crops used worldwide for direct human consumption (Klein et al. 2007). There is concern that production of agricultural crops that rely on various bee species for pollination could face declines adversely affecting associated industries (Rader et al. 2009; Howlett & Donovan 2010; Lentini et al. 2012; Newstrom-Lloyd 2013) due to declines in bee populations. Globally, honeybees are adversely affected by the spread of the *Varroa destructor* mite and Colony Collapse Disorder, although the latter has not been recorded in New Zealand (Stevenson et al. 2005; Donovan 2007; Rader et al. 2009), and a decline in food source availability (Allen-Wardell et al. 1998). Within New Zealand, control measures have been implemented to contain the spread of *V. destructor* within commercial hives (Stevenson & Smale 2005), but feral honeybees have been dramatically reduced in abundance (HD Wilson, pers. comm.) and Donovan (2007) expected colonies in both the North and South Islands of New Zealand to die. These issues have focused attention on the roles of native pollinators, which were shown in a global study to be important even to crop pollination (Garibaldi et al. 2013). Rader et al. (2009) suggest further study of the biology of unmanaged pollinators is warranted, having established that *Brassica rapa* var. *chinensis* (pak choi) pollination services could potentially replace those provided by the honeybee.

Historically, New Zealand lacked any long-tongued or large social bees (Newstrom & Robertson 2005) traditionally known to provide pollination services, but still had a wide range of indigenous pollen and nectar feeding species. These include 41 short–tongued bees (Donovan 1980, 2007; Read

et al. 1990), moths, butterflies, beetles, flies (Goulson 2003; Newstrom & Robertson 2005), birds (Kelly et al. 2010), bats (Godley 1979; Arkins et al. 1999) and lizards (Whitaker 1987). Since the arrival of Europeans in the early nineteenth century, eight large bee species, five of them social, have been introduced to New Zealand to assist in the pollination of agricultural plants (Donovan 2007; Howlett & Donovan 2010). These exotic bees also visit the flowers of numerous native plants (Butz Huryn 1995). New Zealand native bees provide a significant contribution to the pollination of native plants (Kelly et al. 2006; Donovan 2007) and also appear to be supporting pollination of some commercial crops (Donovan 2007; Rader et al. 2009; Howlett & Donovan 2010; Howlett et al. 2011).

Lasioglossum sordidum (Halictidae) is one of New Zealand's most common ground-nesting bees and is found throughout the country (Quinn 1984; Donovan 2007). Its adults are more numerous than those of all other native bees on the east of the South Island (Donovan 2007). This bee is classed as solitary although several females may forage from the same nest, and multiple generations could be active at the same time. This suggests some limited social organisation (Donovan 1980, 2007). Fertilised females overwinter in nests, emerging as early as late winter as the ground begins to warm (Donovan 1980, 1983, 2007). New males and females start appearing in late spring and are active through warmer months although each bee probably lives no longer than 6–8 weeks (Donovan 1980, 2007). Their length (4.9–6.1 mm; Donovan 2007) is considerably smaller than that of the introduced honeybee (*Apis mellifera*), which measures around 12–13 mm (Donovan 1980). *Lasioglossum sordidum* regularly go unnoticed owing to their small, fly-like appearance (Donovan 2007). They are small and agile, and will push their way into

floral tubes or open flowers, sometimes leaving very little of the bee exposed (Godley 1979; DB pers. obs.). In general, their short tongues do not restrict their foraging for pollen (Goulson 2003), although this is not the case for some plant species e.g. *Medicago sativa* (Donovan 2007). Being polylectic, *L. sordidum* forage pollen from a wide range of ornamental plants, both native and introduced to New Zealand, as well as introduced crop plant species (Donovan 2007).

Nests consist of branching tunnels penetrating to a depth of around 400 mm within a fine-grained substrate (Donovan 1980; Quinn 1984; Wojcik & McBride 2012). Hundreds of female bees can nest within a few square metres of bare soil (Donovan 2007). Pollen is carried by the females on the scopae on their hind legs, thorax and to some degree on their abdomen (Donovan 1980, 2007; Quinn 1984).

Information on the foraging range of bee species, especially solitary native bees, is contributing to a better understanding of the potential pollination services they could provide as well as the formulation of strategies for their conservation (Gathmann & Tscharntke 2002; Goulson 2003; Kim et al. 2006; Greenleaf et al. 2007; Zurbuchen et al. 2010). Various methods can be used to study these issues, including radar, feeder-training, and bee relocation. Another method involves the identification of pollen grains collected from individual bees and then measuring the distance to the nearest plant of the species collected (Beilenson 1991; Greenleaf et al. 2007).

The aims of this study were: (1) to identify the plant taxa, as much as possible to the species level, of the pollen being collected by *L. sordidum* in an urban botanic garden where there was a diverse and known assemblage of woody and herbaceous plants of mixed native and exotic origin; (2) given the diversity of pollen sources, to discover whether individual *L. sordidum* collect pollen from multiple plant taxa or show a preference in a foraging bout for pollen of a single plant taxon or a few plant taxa, that is, exhibit specialisation in their pollen harvesting (MacIvor et al. 2014); (3) if individual bees specialise, whether this is constant throughout the population or varies among individuals; and (4) to establish the minimum foraging distance travelled by *L. sordidum* to these known floral resources and to establish if this is related to the number and proportion of pollen taxa collected.

Methods

We worked in the Christchurch Botanic Gardens (hereafter the Botanic Gardens) (43° 31.9' S, 172° 37.0' E), central Christchurch, New Zealand, which contains a wide range of exotic and native flowering plants. A preliminary survey showed that there were many *L. sordidum* nesting sites in the Botanic Gardens, both in highly visible locations within areas of bare compacted soil, and beneath the canopies of vegetation and under mulches. Bee activity was most noticeable during the warmth of the middle of the day, and most sampling was subsequently undertaken between 1100 h and 1300 h during sunny episodes rather than when clouds created shade.

Aggregations of nesting sites were chosen for study within the area known as the pinetum. This contained a collection of mixed coniferous trees with a predominantly grass understorey in which there were occasional flowering plants of *Taraxacum officinale*. We undertook our research in this area because, unlike most of the Botanic Gardens, it experienced low foot traffic from the public, reducing disturbance to bees and their nests. The area is bordered to the north, west and south by roads,

and beyond these by Hagley Park's closely mown sports fields that extend a distance of 400–900 m devoid of plants other than sports turf species bordered by European wind-pollinated trees (and flowering cherries, which had finished flowering at the time of our sampling). This location meant that the Botanic Gardens would be the closest source for any pollen type occurring in them, although the bees could have flown greater distances in other directions to visit private gardens beyond Hagley Park. Over 99% of the pollen types identified on bees was found on plants growing in the Botanic Gardens. Some of the seven rare unidentified pollen types could have come from beyond Hagley Park.

We selected two aggregations of nesting sites 145 m apart for sampling. The car park site was located in a shrub garden adjoining a car park, and the Monterey pine site near the base of a mature *Pinus radiata* (or Monterey pine) tree. Each of these contained numerous nest tunnels located in patches of exposed ground. Forty pollen-carrying female bees per site were captured individually as they returned to their nests at the car park (23–24 November 2012) and Monterey pine sites (24–25 November 2012). During these 3 days, minimum and maximum air temperatures were 10–12°C and 20–22°C, respectively.

Digital maps were used to measure the straight-line distance (to the nearest m) between each potential pollen source plant and each nesting site, described as the pollen mapping technique by Greenleaf et al. (2007). These were taken as the minimum distance a bee would need to fly to collect that particular pollen (referred to below as the minimum foraging distance). These minimum foraging distances do not take into account deviations each bee could have made between its nest and the pollen source(s).

Pollen collection and identification

Bees were placed into plastic vials (40 mm long x 10 mm diameter) where they either released their pollen spontaneously or required chilling and rewarming, which resulted in grooming and the prompt release of pollen. All bees were held until the end of the sampling period to prevent resampling of the same bee, and then released back at their respective collection site. Six bees were collected and photographed using a Leica MZ10F stereo–microscope (16x magnification) with Leica DFC310FX camera. Identifications were made using voucher specimens (Simon Litchwark, University of Canterbury) and the key in Donovan (2007).

A pollen reference collection was constructed using specimens collected from plants in flower in the surrounding area between 22 and 27 November 2012. The locations of these plants were recorded in the Botanic Gardens plant database and the locations were checked by reference to experienced field staff working in the grounds. Map references and photographic records were taken for each plant sample. The pollen reference collection included 113 species or cultivars from 50 plant families (21 native and 23 exotic families, and six of mixed native and exotic origin). Examination of pollen from five different taxa from the family Asteraceae indicated that we would not be able to distinguish between such pollens subsequently collected from bees, except in the case of *Taraxacum officinale*.

All pollen specimens (from bees and plants) remained refrigerated until being mounted on slides in gelatin-fuchsin gel (Robertson et al. 2005). Pollen grains were collected from each flower or the interior of each plastic tube by rolling a small cube of gel (c. 7 x 7 x 5 mm) across the surface (Howlett

et al. 2011). This cube was melted on to a microscope slide and covered with a cover slip. Once cool and labelled, the pollen was examined using a Leica DM5000B compound microscope (630x magnification) and Leica DFC310FX camera. A photographic reference collection was produced for all plant pollens. This collection was used together with published identification keys to identify the pollen grains collected from *L. sordidum* (Cranwell 1953; Moar 1993). Three hundred randomly selected bee pollen grains were counted per slide and identified (24 000 pollen grains in total). Slides, insect specimens and pollen were deposited at the School of Biological Sciences, University of Canterbury. Remaining loose pollen is available for further identification techniques including acetolysing (LE Newstrom-Lloyd, pers. comm.).

Analysis

We used linear regression to test for a relationship between distance to the nearest plant of each pollen type and overall mean abundance of that pollen type across all bees. The regression was run in R version 3.1.1 (R Development Core Team 2014). We tested pollen types per bee, predicted from either (1) abundance of the most common pollen type on that bee, or (2) distance to the nearest plant of the dominant pollen type on that bee, using poisson GLMs in R to allow for the integer response variable. The data were not overdispersed.

We were interested in the number of different plant species that each bee had been visiting. This analysis was constrained by the Asteraceae (non-*Taraxacum*) pollen type being common but spanning at least four possible species, so there was an unknown amount of cryptic diversity in the number of plant species visited. We used subsets of the data to estimate the importance of this cryptic diversity. We hypothesized that *Lasioglossum* bees regard the various species within the Asteraceae pollen type as different, since they vary in flower colour, shape and size (see results section). We also hypothesized that the number of individual flower types visited at one time by individual *Lasioglossum* bees is constrained by memory limitations on efficient flower handling (Waser 1986). Under those conditions, if a single bee which carried Asteraceae pollen typically collects from multiple Asteraceae species, it should also carry significantly fewer non-aster pollen types. Since the multiple aster species are counted as a single pollen type, these bees should have fewer recorded pollen types in total. In contrast, if single bees with Asteraceae pollen typically collect from only one aster, the number of non-aster types should not be constrained, and aster-collecting bees should not carry significantly fewer pollen types in total. We tested this by comparing pollen types per bee in two groups: bees with 0–7% Asteraceae pollen type (n = 21) and bees with 14–100% of this pollen type (n = 59). The number of pollen types per bee were compared using a poisson GLM run in R.

Results

The pollen collected from bees contained 23 distinct pollen taxa (Table 1). These included native, exotic, and mixed taxa. Seven pollen types from bees could not be identified, although all of these were rare (combined total 0.34% of the pollen count; Table 1). Pollens of 90 taxa in the reference collection of plants that were in flower at the time were not detected in the pollen collected by the bees.

Asteraceae pollen was by far the most abundant pollen

type, making up 65% of all pollen (Table 1, Fig. 1), and only seven of the 80 bees carried no Asteraceae pollen. It was not possible to identify the pollen to individual taxa from which reference collections had been made (Table 3) except for *Taraxacum officinale*. Although *T. officinale* was present in 39 bee samples (49% of bees) and was the fifth most common pollen type, it was a small part of the total pollen count (3.1%) (Table 1). The second most common pollen was of the native genus *Hebe* (16%), followed by the two introduced genera *Aesculus* and *Yucca* (8% and 3%, respectively). Our test for cryptic pollen diversity within the Asteraceae pollen type found little support for our hypothesis. We found no significant difference in the number of apparent pollen types per bee for the 21 bees with 0–7% Asteraceae pollen (mean of 2.7 pollen types per bee) versus the 59 bees with 14–100% Asteraceae pollen (mean 2.6 pollen types per bee; poisson GLM, Chi^2 = 0.068, df = 1, P = 0.79). This is consistent with each bee typically collecting mainly from a single species within the Asteraceae family.

Several members of the family Myrtaceae (mainly native species and the Australian *Melaleuca steedmanii*) were in flower at the time the study was undertaken. However, only one bee carried any Myrtaceae pollen (1.3% of its pollen was the native *Metrosideros umbellata* plus 1% of other Myrtaceae that could not be identified to finer taxonomic level).

Although there was a wide range of plant taxa available from which to collect pollen, in general, individual bees collected pollen predominantly from a single plant taxon. Thus,

Table 1. The percentage of different pollen taxa present in samples collected from *L. sordidum* bees at two nest sites in the Christchurch Botanic Gardens in November 2012.

	Monterey pine site (%)	Car park site (%)	Mean (%)
Asteraceae	60.57	69.00	64.79
Hebe spp.	21.16	11.31	16.24
Aesculus spp.	4.77	11.69	8.23
Yucca baccata	2.37	3.96	3.17
Taraxacum officinale	3.71	2.54	3.13
Linaria purpurea	2.50	0	1.25
Mazus radicans	1.12	0.95	1.04
Euphorbia glauca	1.95	0	0.98
Lychnis flos-jovis	1.11	0.30	0.71
Unidentified 7	0.25	0.01	0.13
Unidentified 2	0.20	0	0.10
Podocarpus spp.	0.08	0.03	0.06
Aruncus dioicus	0.09	0	0.05
Unidentified 1	0	0.08	0.04
Unidentified 5	0.08	0	0.04
Bulbinella hookeri	0	0.07	0.035
Myrtaceae	0	0.03	0.015
Metrosideros umbellata	0	0.03	0.015
Unidentified 4	0.03	0	0.015
Fuchsia spp.	0.01	0	0.005
Arthropodium cirratum	0.01	0	0.005
Unidentified 3	0.01	0	0.005
Unidentified 6	0	0.01	0.005

a. Monterey pine site
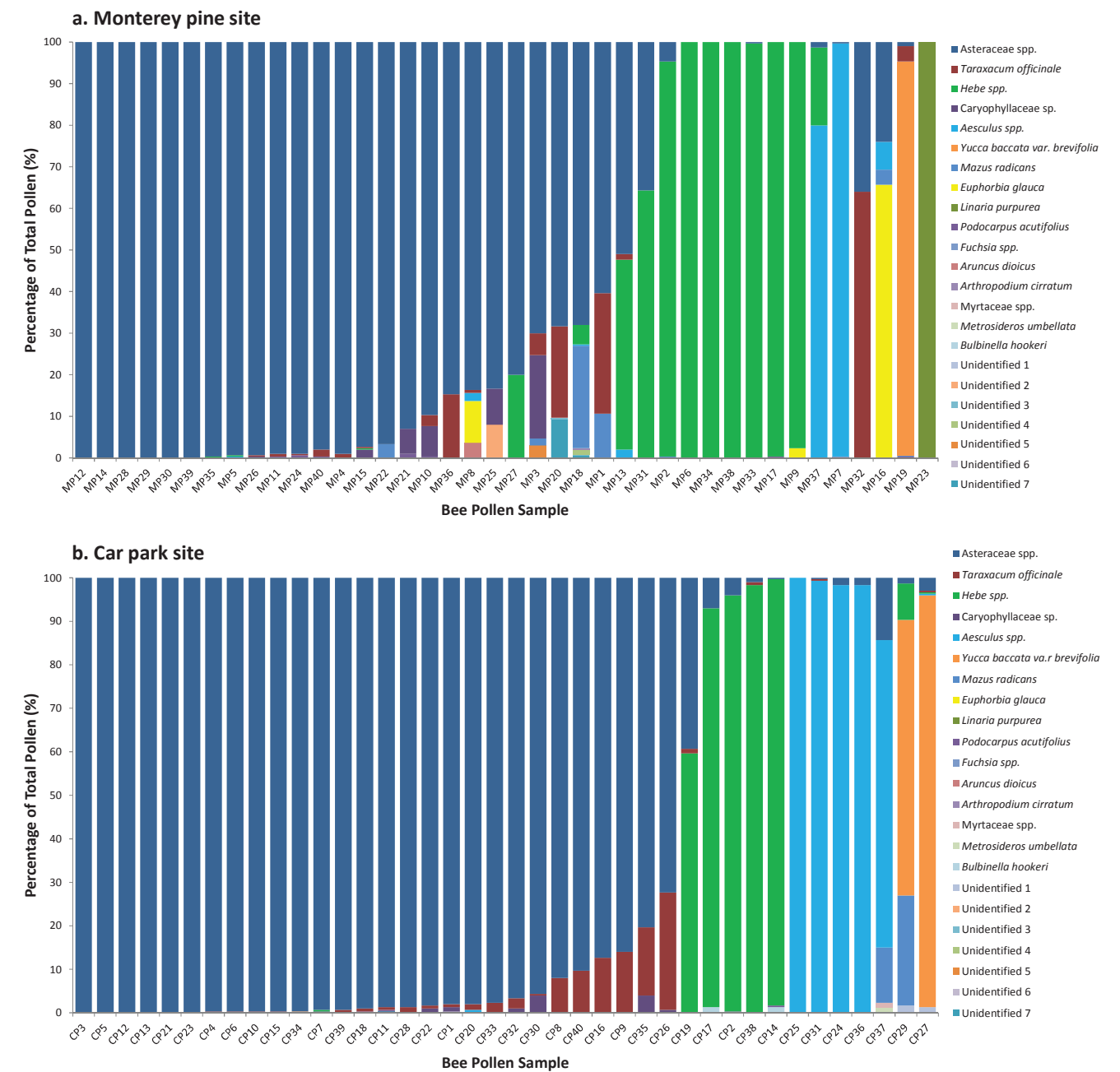

b. Car park site

Figure 1. Percentages of different plant taxa represented in pollen collected from 40 individual *L. sordidum* bees sampled at each of (a) Monterey pine and (b) car park nesting sites within the Christchurch Botanic Gardens.

Table 2. Numbers of *L. sordidum* bees that had collected most (>90%) of pollen of a single pollen type during November 2012, Christchurch Botanic Gardens.

Pollen type	Number of bees with >90% pollen of that type		
	Monterey pine site	Car park site	Total
Asteraceae	16	24	40
Hebe spp.	7	4	11
Aesculus spp.	1	4	5
Yucca baccata	1	1	2
Linaria purpurea	1	0	1
Mixed load	14	7	21
Total number of bees	40	40	80
Mean pollen types per bee	2.63	2.55	2.59

59 out of 80 individual bees (74%) had greater than 90% of pollen from one plant taxon on returning to their nests, and 17 of the 80 (21%) were carrying only a single plant taxon pollen (Table 2).

However, the bees exhibiting this specialised collecting behaviour differed in the plant taxon chosen for collecting (Table 2). For instance, half the bees collected solely or predominantly (>90% of pollen collected) from the Asteraceae (40 bees; Fig. 1). Contrastingly, 14% of the bees collected solely or predominantly from *Hebe*, and 6% from *Aesculus* (11 and five bees, respectively; Fig. 1).

The importance of this between-bee variability is most clearly shown for *Linaria purpurea* (purple toadflax). Pollen of this species represented 1.25% of all pollen but this resulted from a single bee carrying pollen only of *L. purpurea* (Monterey pine site, Fig. 1). No *L. purpurea* pollen was found on any other bee sampled from either site. Similarly, although not as exclusively, *Yucca baccata* constituted 95% of the pollen on two bees (Fig. 1), and 63% and 0.3% of the pollen on two more bees, yet pollen of this species was not found on any of the other 76 bees (Table 2). Because of this pattern of collecting, the overall proportion of total pollen collected of a particular plant taxon was mainly influenced by the proportion of bees that foraged largely or wholly upon that particular plant taxon. This also showed that *L. sordidum* individually specialise on one or a few flower types in each foraging bout, but because individual bees specialise on different flower types, collectively the population was foraging on a wide range of plant species.

Nonetheless, 21 of the 80 *L. sordidum* bees (26%) had mixed loads of pollen from several different plant taxa (mixed load defined as the most common pollen type being <90% of the pollen). For example, one bee had pollen from the Asteraceae, *Hebe* and *Aesculus*, as well as from *Mazus radicans*, *Arthropodium cirratum*, and small quantities of two unidentified plant pollens; another carried predominantly *Yucca baccata* pollen along with pollen of *T. officinale*, *M. radicans* and *Podocarpus* (Fig. 1). On average, bees were carrying pollen of 2.6 plant taxa (Table 2) and the number of pollen taxa was inversely related to the abundance of the most common pollen in each sample (Fig. 2; Chi^2 = 10.57, df = 1, P = 0.001). However, even the mixed loads were usually dominated by few pollen taxa. Counting only pollen taxa that made up at least 10% of a bee's total pollen load, 16 bees had two taxa, two bees had three, and the other 62 had only a single pollen taxon contributing >10%. However, if individual bees had visited multiple different species of Asteraceae or *Hebe* this would not have been detected with our methods.

There was no relationship between the minimum foraging distance for each site to a pollen source of a particular plant taxon and the proportion of that pollen of that taxon in the harvested pollen (Fig. 3; regression F$_{1, 20}$ = 0.11, P = 0.74). In other words, pollen was collected from plant taxa in proportions that bore no relation to the minimum distance the bees would have had to fly to those sources. This lack of relationship is exemplified by pollen of *T. officinale* making only a small contribution to pollen collected overall (3.1%, Table 1) even though plants of this taxon were flowering as close as 2 m from each of the nesting sites. Conversely, pollen of *Aesculus* was found in 8% of the samples even though the closest plants were 173 m from the car park and 235 m from the Monterey pine nest sites (the greatest minimum foraging distance recorded). Moreover, Asteraceae other than *T. officinale* made up 65% of all pollen but were at a minimum foraging distance of 86–168 m (Table 3). Several of the other principal pollen taxa were
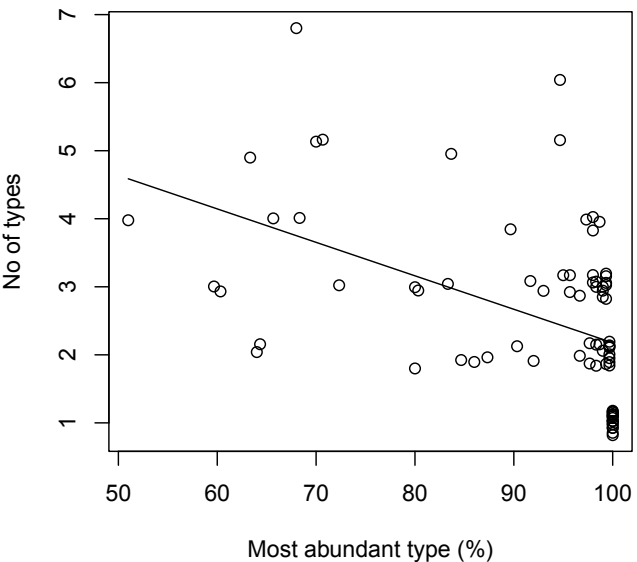

Figure 2. The relationship between the abundance (%) of the most common pollen taxon and the total number of pollen taxa in each sample from 80 individual *L. sordidum* bees from the Christchurch Botanic Gardens. The regression was significant (poisson GLM, Chi^2 = 10.57, df = 1, P = 0.001). The data are jittered vertically to reveal overlapping data points.
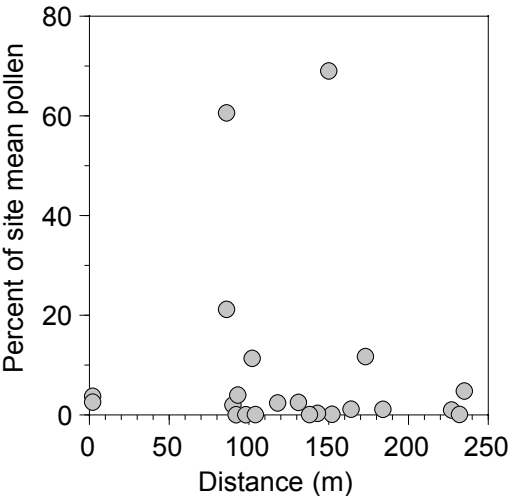

Figure 3. Relationship between minimum foraging distance to a pollen taxon and the proportion of that pollen (%) in pollen samples from 40 *L. sordidum* bees, for each of two nest sites in the Christchurch Botanic Gardens. The regression was not significant (F$_{1, 20}$ = 0.11, P = 0.74).

sourced well over 100 m from the nests, e.g. species of *Yucca*, *Linaria*, and *Mazus* (Table 3). There was also no relationship between distance to nearest plant of the dominant pollen type on a bee and the number of pollen types found on that bee (poisson regression; Chi^2 = 0.481, df = 1, P = 0.49), so bees did not collect more (or fewer) pollen types if they had flown further. It should be noted that these are all minimum distances to the nearest single plant; bees were almost certainly travelling further than this to reach multiple individuals of measured species and/or more distant species where a pollen type covered more than one species.

Table 3. Minimum distances (m) between the *L. sordidum* nest sites and the closest source plant for pollen types found on the bees. Dashes indicate a pollen type not found on bees from that nest site. The Asteraceae species, apart from *Taraxacum*, could not be separated using pollen morphology but we list the closest flowering examples of that family to the nest sites.

Family	Species	Distance (m) to:	
		Monterey pine site	Car park site
Agavaceae	*Yucca baccata*	118	93
Asteraceae	*Brachyglottis* spp.	90	158
	Olearia spp.	111	152
	Pachystegia insignis	105	168
	Ozothamnus leptophyllus	86	150
	Taraxacum officinale	2	2
Asphodelaceae	*Arthropodium cirratum*	98	-
	Bulbinella hookeri	-	232
Caryophyllaceae	*Lychnis flos-jovis*	184	143
Euphorbiaceae	*Euphorbia glauca*	90	-
Myrtaceae	*Kunzea ericoides*	-	257
	Lophomyrtus bullata	-	153
	Leptospermum scoparium	-	257
	Melaleuca steedmanii	-	104
	Metrosideros umbellata	-	138
Onagraceae	*Fuchsia excorticata*	104	-
	Fuchsia procumbens	92	-
Phrymaceae	*Mazus radicans*	164	227
Plantaginaceae	*Hebe* spp.	86	102
	Linaria purpurea	131	-
Rosaceae	*Aruncus dioicus*	152	-
Sapindaceae	*Aesculus* spp.	235	173

Discussion

Lasioglossum sordidum showed a capacity to forage relatively large distances, foraging on pollen sources quite distant from their nesting sites, and the overall contribution of a plant species to the pollen total was unrelated to minimum distances to that species. This could have been driven by preferences for some flower types over others, and preference for mass flowering rather than small scattered plants (Primack 1978). The bees had strong preferences, with 23 pollen types found on bees but 90 locally flowering species not detected on the sampled bees. Although the grassed area surrounding the nesting sites contained exotic *T. officinale* (Asteraceae), these small herbaceous plants were present at low density, possibly providing limited foraging opportunities. Contrastingly, seven bees flew beyond numerous native and exotic plants to reach and forage predominantly on the large flower crops of *Aesculus* trees. Beil et al. (2008) observed a similar result with *Lasioglossum calceatum*, which travelled 700–1000 m to collect pollen from *Aesculus hippocastanum*. The relative abundance of pollen available for harvest on host plant taxa was not quantified in our study so the apparent preferences exhibited by the bees could have reflected variation in pollen supply at the time.

The foraging range of *L. sordidum* is comparable with other small bee species, which on average travel approximately 250 m (Wojcik & McBride 2012). A flight intercept study comparing different insects found *L. sordidum* travelling 200 m, but none was recorded within traps set at 300 m (Rader et al. 2011). Zurbuchen et al. (2010) suggested that a foraging distance of a few hundred metres (100–300 m) was typical for most individuals in a population of small bees, although some could travel much further. This maximum foraging range is comparable to our data (Table 3), although our distances are minima and bees could have been going much further. These combined results may provide a good estimate for the average foraging range of *L. sordidum* and provide a better understanding of their foraging landscape (Greenleaf et al. 2007).

Individual *L. sordidum* typically demonstrated flower constancy by apparently selecting pollen primarily of one or two types on any foraging session, consistent with previous reports (Primack 1983; Waser 1986; Beilenson 1991). This may be to maximise foraging efficiency, given some limits on the ability of bees to remember and handle multiple flower types within one session (Waser 1986). Nonetheless, numerous floral rewards were being collected across the whole population, because of variation between individual bees in their chosen flower types at the time of sampling. We reiterate that within some of our common pollen types, particularly Asteraceae, we have no way of knowing if individual *L. sordidum* bees were visiting multiple different species within the same pollen type. However, the test of pollen types per bee for bees with and without Asteraceae suggested this cryptic diversity might be small. Further work on this (e.g. using DNA to identify pollen to plant species) would be very helpful.

There have been several reports of *L. sordidum* foraging on members of the Asteraceae, including *Pachystegia insignis* (Donovan 2007; Webber et al. 2012; DB pers. obs.), *Brachyglottis* spp. (Webber et al. 2012; DB pers. obs.) and *Olearia* spp. (Primack 1983; Donovan 2007). *Hebe* spp. are also reported as providing numerous foraging opportunities for *L. sordidum* (Primack 1983; Donovan 2007; Webber et al. 2012). *Lasioglossum sordidum* have previously been noted visiting *Bulbinella,* members of Caryophyllaceae, *Aesculus* (Donovan 2007) and *Mazus* (Primack 1983), although there are

no previous reports of them foraging on *Linaria purpurea*, *Yucca baccata* or *Aruncus dioicus* according to the comprehensive data presented by Donovan (2007).

The relatively small amounts of pollen from the Myrtaceae in samples collected in the current study was surprising because Webber et al. (2012) had earlier recorded *L. sordidum* visiting species from this family at a nearby location, both exotic (*Callistemon polandii* and *Leptospermum nitidum*) and native (*Leptospermum scoparium* and *Lophomyrtus × ralphii*). Others have also reported *L. sordidum* foraging upon *Kunzea ericoides*, *Leptospermum scoparium*, *Lophomyrtus* spp. and *Melaleuca* spp. (Primack 1978, 1983; Donovan 2007; Webber et al. 2012).

Native bees are often outnumbered by *A. mellifera* on various floral resources (Goulson 2003; Donovan 2007). Moreover, *A. mellifera* starts foraging earlier in the day than the native bee populations (Goulson 2003), so food resources may be depleted before *L. sordidum* start foraging. However, this competition is not thought to limit the successful foraging of *L. sordidum* (Donovan 1980, 2007).

Agricultural intensification and other land use changes can reduce suitable nest and foraging sites within certain areas while creating other opportunities for bees (Klein et al. 2007). During a development and relocation project for *Leioproctus huakiwi* larvae from Akaroa, Banks Peninsula, to Lincoln, mid-Canterbury, *L. sordidum* individuals promptly occupied the holes that had been deliberately prepared within the bare soil of the new *L. huakiwi* nesting site (Donovan et al. 2010), and *L. sordidum* bees have been studied visiting various crops, including kiwifruit, blueberries, onion, and pak choi (Macfarlane & Ferguson 1983; Macfarlane 1992; Howlett et al. 2005, 2011; Rader et al. 2009, 2012). While it is beyond the scope of our work to extend our findings to specific agricultural landscapes, our results add to those of others from garden situations (Greenleaf et al. 2007; Wojcik & McBride 2012) and indicate patterns of pollen collecting that might have relevance to the design of habitat enhancements for *L. sordidum* in these settings.

We successfully identified over 99% of pollen grains taken from the sample *L. sordidum* bees returning to two nesting sites in the Botanic Gardens. While individuals were specialists, the collective populations of *L. sordidum* were generalist foragers as individuals varied in their plant choices, travelling at least 70–250 m to collect from a range of both native and exotic pollen types. Although there could be further cryptic foraging diversity in pollen taxa containing multiple plant species, even the flower diversity confirmed here shows that *Lasioglossum sordidum* visit the flowers of a wide range of plant species. These native bees are so small they are often overlooked, but they could be making an important contribution to pollination.

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