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Factors influencing the foraging activity of the allodapine bee *Braunsapis puangensis* on creeping daisy (*Sphagneticola trilobata*) in Fiji

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Keywords

Bees, invasive plants, pollinators, South Pacific

Introduction

There is growing concern regarding the global decline of honey bee populations and the implications of this demise for the pollination of entomophilous crops (Potts et al. 2010, Groom and Schwarz 2011; Cornman et al. 2012). In the future we may rely on other insect species to perform crop pollination services, including naturally-occurring native or introduced species of bees (e.g. Rader et al. 2009). Pollination success of generalist plants tends to be positively related to pollinator diversity, so any habitat modifications that increase the number of pollinating species present at a site would tend to be of some inherent value (Hoehn et al. 2008, Albrecht et al. 2012). The deliberate sub-planting of crops, orchards or vineyards with flowering plants (such as buckwheat, *Phacelia* and *Alyssum*) is already employed as a means of attracting beneficial invertebrates by providing a nectar or pollen reward (Irvin et al. 2006). A similar process involves the leaving of field margins fallow to allow a higher diversity of flowering 'weeds' to grow, which again promotes a higher diversity of invertebrate predators and pollinators to occur (Cowgill et al. 1993).

The situations described above give the impression that the presence of some exotic flowering plants may be of benefit by encouraging higher numbers of pollinating species to occur at a site. Outside of agro-ecological systems, many studies have indicated that even flowering plants considered as invasive may have positive effects on insects, especially on nectar and pollen feeding species. For example, in Europe and North America, the exotic highly invasive Himalayan balsam (*Impatiens glandulifera* Royle) is visited by a high diversity of native pollinating insects, including bumble bees (*Bombus* spp), solitary bees, and domestic honey bees (*Apis mellifera* L.) (Showler 1989, Stary and Tkalcu 1998, Nienhuis et al. 2009).

Sphagneticola trilobata (L.) Pruski (Asteraceae) is an emerald-green creeping plant that has bright yellow daisy-like flowers. The plant is of Central/South American origin and is now found in many South Pacific island states, where it has become established on disturbed sites, such as waste land, road sides, riverbanks and the sea shore (Whistler 1995). The species is thought to have been introduced to Fiji sometime in the early 1970s as a garden ornamental near Suva Point, on the main island of Vitu Levu (Thaman 1999). A recent survey in the Suva area reported over 100 species of arthropods associated with road side patches of *S. trilobata*, including Hymenoptera such as parasitoid wasps, honey bees and solitary bees (Prasad and Hodge in press). One species of solitary bee, *Braunsapis puangensis* (Cockerell, 1929) (Apidae: Allodapini) was locally abundant on patches of *S. trilobata* in the Laucala Bay area of Suva. This bee species is probably of Indian origin and was most likely carried to Fiji by anthropogenic means (Groom and Schwarz 2011, Davies et al. in press). The genus *Braunsapis* is listed in the Fijian fauna provided by Evenhuis (2007), but does not appear in the older lists of Michener (1965), Fullaway (1957) and Turner (1919). Shenoy and Borges (2008) examined the diurnal activity patterns and pollination behaviour of this species in India and the phylogeny of the group has received some detailed attention (Bull et al. 2003, Schwarz et al. 2004, Fuller et al. 2005). The genus has also been studied in terms of its social parasite behaviour (Reyes and Sakagami 1990, Batra et al. 1993).

The aim of this study was to obtain empirical data on the activity and distribution of *Braunsapis puangensis* in the Suva area of Fiji and examine its association with *Sphagneticola trilobata*. We studied spatial patterns on a local scale by recording its presence or absence on patches of *S. trilobata* along roadsides, and carried out long term sampling over 14 months to gain information on patterns in seasonal occurrence. A more detailed study was performed at a single site to investigate daily foraging patterns and examine the effects of environmental conditions on *B. puangensis* activity.

Methods

Field survey of patches of *Sphagneticola trilobata* in the Suva area

Twenty-two patches of *Sphagneticola trilobata* were selected to give widespread coverage of the Greater Suva area (including Lami and Nasinu) and the surrounding area (Rewa Delta, Nukulau Island) (Table 1). All the patches of *S. trilobata* sampled were greater than $4m^2$ in area and close to roadsides or tracks. Insects were either sampled using a sweep net or obtained directly from the flowers using a battery-powered aspirator. To avoid over sampling the bees, only the presence/absence of *Braunsapis puangensis* was recorded at some locations. The coordinates of each site were recorded using a geographical positioning system ['*e*trex'; Garmin Ltd, Southampton, UK] and these used to plot a map of the sites using Microsoft MapPoint (Figure 1).

Seasonal activity patterns of *Braunsapis puangensis*

Long term monitoring of *Braunsapis puangensis* was carried out using yellow pan traps placed out under the eaves of a house on The University of the South Pacific (USP)

Table 1. The presence or absence of *Braunsapis puangensis* on twenty two patches of *Sphagneticola trilobata* in the Greater Suva area visited in April 2011.

Site no.	Site Identification	Latitude	Longitude	*B. puangensis*
1	USP, Campus library	-18.150	178.445	✓
2	USP, Lower Campus	-18.150	178.453	✓
3	USP, Upper Halls	-18.149	178.445	✓
4	Colo-i-Suva	-18.091	178.458	✓
5	Bowling Club	-18.149	178.423	-
6	Muanikau	-18.150	178.450	✓
7	Vatuwaqa Cemetery	-18.141	178.456	-
8	FNU Hospitality	-18.163	178.431	✓
9	Lami rubbish dump	-18.114	178.425	-
10	Lami town	-18.114	178.409	-
11	Laucala Beach	-18.112	178.478	-
12	Golf course	-18.127	178.462	-
13	Khalsa Road	-18.087	178.465	-
14	Savura	-18.082	178.443	-
15	Namadi heights	-18.109	178.446	-
16	Nadawa	-18.102	178.499	-
17	Kalabo	-18.087	178.494	-
18	Caubati	-18.104	178.469	-
19	Ram Lakhan Park	-18.128	178.441	-
20	Cunningham Road	-18.100	178.456	-
21	Nukulau Island	-18.173	178.514	✓
22	Rewa Delta	-18.074	178.574	✓

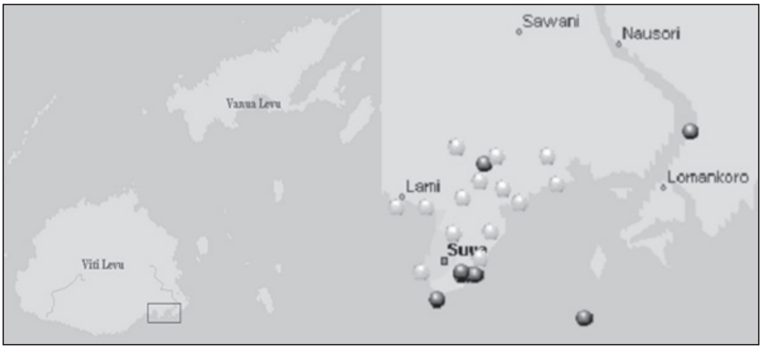

Figure 1. Maps of major Fiji Islands showing general location of study area, and of Greater Suva indicating locations of patches of *Sphagneticola trilobata* sampled in the current study. Dark circles indicate presence and white circles indicate absence of *Braunsapis puangensis.*

Upper Campus within a patch of *Sphagneticola trilobata* (and a few other low-lying plants). The traps consisted of 30 cm × 25 cm rectangular plastic bowls (20cm deep) that were half filled with water to which a few drops of household detergent had been added. Sampling was continuous, using two traps at all times which were emptied once each week. The insects collected in each calendar month were then pooled. Collecting was carried out for 14 months, from May 2010 to June 2011.

Daily activity patterns of *Braunsapis puangensis* and the effect of environmental parameters

A single patch of *Sphagneticola trilobata* on The USP Upper Campus was used to monitor daily activity patterns of *Braunsapis puangensis.* Activity was estimated by dividing the patch of flowers into three sectors (each 2 m × 2 m) and performing a 30 second count of individuals in each sector. A mean of the three counts was then obtained. Attempts were made not to count the same individual more than once. This process was repeated every hour, from just prior to dawn and to just after dusk, and was repeated over five separate days (during April 2011). Light intensity, relative humidity and temperature were measured on each occasion using electronic meters.

The whole procedure was repeated in May 2011, but on this occasion the activity of the bees was measured during dry periods and during rain until there were five replicates of bee activity for each hourly interval for both dry and wet conditions.

Results

Braunsapis puangensis was recorded at eight of the twenty two sites sampled (Table1; Figure 1). There was a cluster of sites where *B. puangensis* was present at Suva Point, but

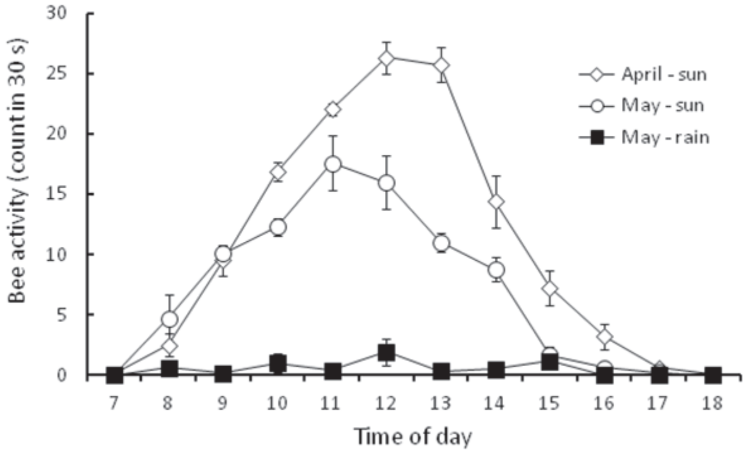

Figure 2. *Braunsapis puangensis* activity from 7am to 6pm on a single *Sphagneticola trilobata* patch at The University of the South Pacific, Laucala Campus (individuals counted in 30 s; mean ± SE, $n = 5$). Observations were made during sunny weather in April 2011, and during sunny and rain conditions in May 2011.

Table 2. Correlation of environmental factors and activity of *Braunsapis puangensis* in a single patch of *Sphagneticola trilobata* on the USP Laucala campus (April 2011). Values given are r_s, Spearman's rank correlation coefficient ($n = 60$; $P < 0.001$ in all cases).

	Relative Humidity	Light Intensity	Bee Activity
Temperature	-0.79	0.85	0.87
Relative Humidity	-	-0.77	-0.78
Light Intensity	-	-	0.86

other sites were quite widespread, from the coastal sites in Laucala and Nukulau Island to the inland forests at Colo-i-Suva (Figure 1).

The activity of *Braunsapis puangensis* observed in May was generally lower than that observed in the April survey at any given time point, but the daily patterns in activity were similar (Figure 2). In fine weather, the activity of the bees increased steadily from 8am, reached a peak around mid-day and then decreased through the afternoon. No *B. puangensis* were observed on the patch of *Sphagneticola trilobata* on the USP campus prior to 7am and after 6pm.

The environmental parameters measured were all co-correlated, with high mid-day temperatures being associated with high light and low relative humidity, and lower temperatures recorded early morning and late afternoon being associated with lower light levels and higher relative humidity (Table 2). Therefore the activity of *Braunsapis puangensis* displayed an association with a set of environmental conditions, activity having a strong positive correlation with temperature and light intensity, and a strong negative correlation with relative humidity (Figure 3; Table 2). The activity of the bees virtually ceased during periods of rain (Figure 2), although bees were often observed foraging soon after the rain had stopped.

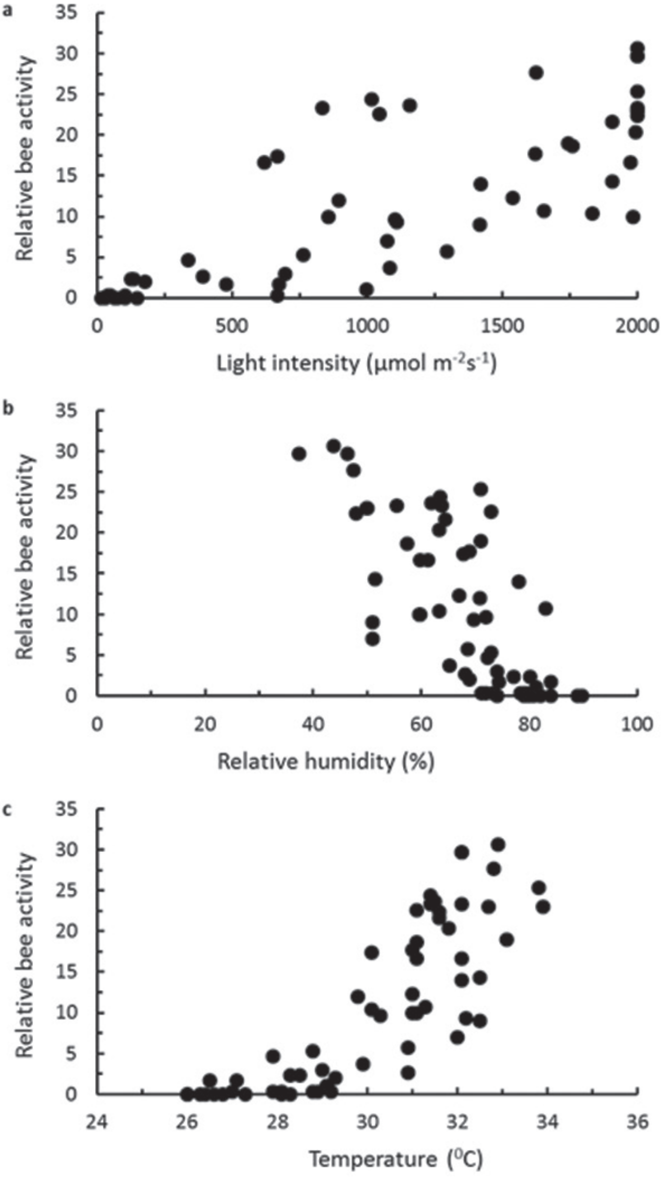

Figure 3. The relationship between activity of *Braunsapis puangensis* (counts in 30 s) and **a** light intensity **b** relative humidity and **c** temperature at a single patch of *Sphagneticola trilobata* on the USP Laucala campus during fine weather in April 2011.

Braunsapis puangensis was recorded in all 14 monthly samples, indicating that adults were present and active in the Suva area over the whole annual cycle. However, the use of water traps as a collecting method for these bees was largely unsuccessful. *Braunsapis puangensis* was only recorded in very low numbers (between 1 and 4 individuals each month: data not shown), even when foraging activity was observed to be high in the surrounding area. Thus, due to the constant low catch, there were no obvious seasonal patterns in *B. puangensis* abundance revealed by this method.

Discussion

The frequency of occurrence of *Braunsapis puangensis* over the sample sites (8 of 22) was lower than we had anticipated. Our initial expectations were based on observations of foraging activity on patches of *Sphagneticola trilobata* in or near the USP campus in Laucala Bay, where *B. puangensis* was common (see Figure 1), often seen in high numbers (see Figure 2) and found regularly throughout the year. The road-side samples were all taken around mid-day in fine weather so, based on the activity patterns observed for this species, if adults were present they would likely have been active when collecting was performed. *Braunsapis puangensis* has been observed on *S. trilobata* at other locations on the south of Viti Levu (e.g. Pacific Harbour and Sigatoka; S. Hodge 2011 pers. obs.), and Davies et al. (in press) give a record of *B. puangensis* to the north of Viti Levu. Our observations likely represent a 'snap shot' of the bee distribution among patches of *S. trilobata* on those sampling days: revisiting the same patches in the future may reveal a different, dynamic aspect, to patch occupancy. However, the occupation level of patches (36%) indicates that *B. puangensis* may not be as ubiquitous on this species of flower as we had first thought, and that further work is required to establish what factors are influencing the distribution of *B. puangensis*, both among patches of *S. trilobata*, on other species of flowering plant, and over the island as a whole.

The daily activity patterns of *Braunsapis puangensis* are similar to those recorded for other bee species. Shenoy and Borges (2008) also found that *B. puangensis* was active throughout the day in Western Ghats of India, although visits of the bee to flowers of *Humboldtia brunonis* Wall. (Fabaceae) appeared more frequent in the morning, with no records beyond early afternoon. Foraging of wild bees and wasps can be strongly correlated to environmental factors (Vicens and Bosch 2000, Wang et al. 2009) and the high levels of *B. puangensis* activity around midday indicated that this species preferred high light levels and warmer conditions (even considering the lowest temperature recorded was 26°C). The virtual cessation of activity during rain can also be linked to these findings: during many of the periods of (sometimes intense) tropical rain we encountered in Suva light levels dropped considerably and relative humidity naturally reached saturation levels. The onset of rain can dramatically reduce foraging activity in Hymenoptera, although, as seen in our study, activity often recovers once bouts of rain have ceased (Vicens and Bosch 2000, Kasper et al. 2008). The daily activity pattern of bees has implications for sampling protocols when attempting to analyze the details of pollinator networks. If the various pollinating species have different diurnal patterns, and respond differently to climatic factors, then the pollinator assemblage recorded could be specific to the immediate weather conditions and the time of day the sample is taken (Baldock et al. 2011).

Solitary and/or native bee species are considered an important resource in terms of pollination of crop species (Groom and Schwarz 2011) and *Braunsapis* is already known to be an important pollinator of native plants (Anderson and Symon 1988, Shenoy and Borges 2008). The most conspicuous Hymenoptera we recorded on *Sphagneticola trilobata* were *Apis mellifera* and *Braunsapis puangensis,* both introduced species in Fiji. Thus it is important to realize that although *S. trilobata* is considered an invasive 'nuisance weed' in one context, it may be of value to crop growers, and commercial honey producers, by attracting and augmenting local populations of pollinating insects.

There has been some fairly wide-ranging, albeit sporadic, published work on the Hymenoptera of Fiji. Turner (1919), Brues (1922) and Fullaway (1957) provided early checklists of species in the islands, which has recently been updated by Evenhuis (2007). There has been the occasional publication on honey bees and bee products (e.g. Anon 1985, Anderson 1990, Prasad 2007, Saraf et al. 2009) and consideration of the ecology of the Formicidae (e.g. Ward 2008, Sarnat 2008). Recently, the biogeography and evolutionary pathways of South Pacific bees have been the focus of detailed investigation (Groom and Schwarz 2011, Groom et al. 2013, Davies et al. in press). Our investigation represents preliminary ecological work on aspects of the ecology of an introduced bee utilizing a naturalized invasive plant. Our results indicate that adult *Braunsapis puangensis* are present in Fiji throughout the year, and its abundance on patches of *Sphagneticola trilobata* varies both temporally and spatially. Future work should extend these studies by examining the nesting behaviour of *B. puangensis* in Fiji, exploring the residence time and 'departure rules' of foraging bees on *S. trilobata* (and other species of flowers), and attempt to gain similar basic data on native species of pollinators and their natural and agricultural host plants.

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