

Is there a positive correlation between bee size and size parameters of the flowers the bees visit for pollen to provision their nests?

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Abstract

In this study I tested if there is a correlation between bee size and size parameters of flowers the bees visit for pollen. In the plant community evaluated there are not many characteristics restricting the use of pollen by bees. Most of the plants analysed have open corollas and/or present pollen with easy accessibility. Small bees can visit all sizes of flowers and they are more generalist; nevertheless large bees are not restricted to large flowers: they can also visit flowers with the alighting place smaller than their body size. Although the amount of pollen is important to attract a diverse and abundant rate of visitation this characteristic is not restrictive as the bees do not always visit flowers just in search of this resource. This was the first study analysing the flower characteristic from the pollen perspective. The results revealed that size of the alighting place, amount of food and the distance between pollen and nectar are important characteristics shaping the interaction between plants and bees.

Key words: morphometric floral traits, pollen, bee size.

Introduction

In many different plant communities, bees are very important for pollination. For example, bees pollinate one or more cultivars of 66% of the world's 1,500 crop species and are directly or indirectly essential for an estimated 15–30% of food production (Kremen *et al.* 2002). Moreover, in Brazilian Savannah 80% of plant species are bee pollinated (Silberbauer-Gotsberger & Gotsberger 1988).

Most females of bee species collect pollen and nectar to feed their offspring in their nest (Williams & Tepedino 2003, Alves-dos-Santos *et al.*, 2006). However, pollen is the essential component of the larval food (Simpson & Neff 1981, Gathmann & Tschardt 2002) providing a source of protein, carbohydrate, vitamins and minerals for them (Bell *et al.* 1983).

Recently many studies have been exploring patterns of flower visitation by pollinators into networks that provide information about the use of resources and associations of animal visitors (Bascompte *et al.* 2003, Olesen *et al.* 2007). In this context, Stang *et al.* (2006, 2009) used floral characteristics related to nectar consumption to predict visitation webs. It is also important to take a pollen perspective as pollen represents the most expensive resource from the plant's viewpoint (Primack 1978), and also some species of bees visit different plants for pollen than for nectar (Leleji 1973).

To understand fully the ecological factors that influence the interaction between flowers and bees in this work I wanted to see **if there is a positive correlation between bee size and size parameters of the flowers the bees visit for pollen to provision their nests**. I predicted that small bees would visit all flower sizes in search of pollen, as the pollen is more accessible than the nectar which sometimes can be protected in spurs or narrow tubes (Castellanos *et al.* 2004). Furthermore small bees can collect pollen from different flower sizes, as they are small and can land in all kinds of surfaces. I therefore predicted that I would find small bees collecting pollen grains from small and big

flowers. In contrast, as animals with high energy requirements may not forage in flowers that do not offer enough caloric reward (Heinrich & Raven 1972), and large bees might visit larger flowers because of morphological constraints (i.e., nowhere to land on very small flowers, or stems won't support their weight), I predicted that I would find big bees visiting just medium and big flowers. I expected as a result of this work to find a network structure based on pollen availability and morphology not so different to the other networks for pollination systems or maybe with a small compartmentalization if large bees do not visit small flowers.

Materials and Methods

Study site

The study was carried out in June-July 2009 at the Rocky Mountain Biological Laboratory (RMBL), at 2900 m elevation, Crested Butte, Colorado, USA.

Flower size parameters

To obtain the mean of the flower size of plants in the community I collected five flowers of each of 27 different plant species and conducted measures on different floral traits using a digital calliper under a dissecting microscope. I hiked once a week in "401" area to add different species as they started to appear.

The specific parts of the flowers that I measured were: number of anthers, height of anthers (distance between the pollen and nectar), anther size, depth of the corolla tube (nectar holder tube; when the corolla was open this parameter was scored as 0 mm). The corolla diameter (measured in the middle of the corolla), alighting place (distance between the entrance of the corolla tube and the functional border of the pollination unit or blossom) (Faegri and van der Pijl 1979, Stang 2006). The entrance of corolla (the diameter of corolla measured in the entrance of corolla), and the diameter of

inflorescence. The flowers were then classified according to the pollen accessibility: “easy” when the anthers were exposed or “difficult” when the anthers were protected by any kind of floral structure. The anthers were classified according to the dehiscence. To have an idea of the amount of pollen food available to bees, I multiplied the number of anthers by anther size.

Flower visitor observations

I selected 12 different plant species with different flower sizes to make observations. Each plant species was observed ca. one hour distributed in 6 sessions of 10 minutes on different days. All bee species recorded collecting pollen were netted for identification and to have their body size weighed and measured. The bees were frozen and in the laboratory they had their pollen removed from the body with a small cube of fuchsin jelly (Kearns & Inouye 1993). The fuchsin jelly cube was placed on a glass slide with a cover slip, and melted.

To confirm if the pollen grains belong to the plant species the bee was collected on, I compared it using a compound microscope and a reference pollen collection. Only bees that had pollen corresponding with the plant it was collected on were included in the analysis.

Visitor traits

The bees were identified to species or genus level when it was possible. All specimens are stored in the Thomson laboratory at the RMBL. Size parameters were measured in a total of 75 specimens. I used a digital calliper and measured the body dimensions under a dissecting microscope.

The parts measured were: total body length, which correspond to the head + thorax + abdomen. Those parts were also measured separately. After that, the bees had their body weighed with a digital balance.

Data analysis

Statistical analysis was performed using BioEstat 5.0. Relationships between flower parameters and bee size were tested with Spearman (r_s) correlations because variables did not present normality. I tested which of the flower's size parameters were correlated with the bee's size.

Based on the plant-visitor observations, I created a plant-flower by pollen consumers (A X P) matrix in which a filled cell indicates the interaction from species "a" foraging on flowers of plant species "p"; then I represented that matrix in a network graph where the line represents the presence of interaction (see Vázquez *et al.* 2009, Alarcón *et al.* 2008).

I calculated the nestedness of the matrix using the binary version of the Animals x Plants networks with the ANINHADO program (Guimarães and Guimarães 2006). This program calculates the matrix temperature (T), which is a measurement of how much a matrix differs from perfect nestedness. The Temperature can vary from 0° (perfect nestedness) to 100° (absence of nestedness). The nestedness is defined as $N = (100 - T / 100)$, where values near to 1 indicate high nestedness and values near to 0 mean absence of nestedness (Bascompte *et al.* 2003).

Results

During the months June and July I collected and measured 27 plant species from 16 families. These plant species presented a great variety of morphologies and sizes (Appendix 1). From the 12 plant species monitored for visitation (Table 1) I collected 84 bees, 75 of them presenting pollen grains in their body corresponding with the flowers on which they were observed.

With exception of *Rosa woodsii*, that do not produce nectar, all plant species were visited by bees for both resources: nectar and pollen. Apparently bees visit flowers principally in search of nectar and secondly for pollen. The most generalist bee species was *Dialictus* sp. which was found on eight different plant species. The most generalist plant species was *Rosa woodsii* which received visits from nine different bee species (Appendix 2, figure 9).

There is a preponderance of on small flowers (figure 1) and small bees (figure 2) in the community. However, the size of bees is not positive correlated with most of the size parameters of flowers they visit to collect pollen. As the total length of bees is positively correlated with the thorax +head ($r_s = 0.87$, $p < 0.001$, figure 3) I used the last parameter in some analyses as that part can be measured with more accuracy.

Consistent with my prediction, small bees are able to visit all flower sizes in search of pollen. For example, there is no correlation between the alighting place of flowers and the total length of bees ($r_s = -0.09$, $p = 0.40$, figure 4), nor between the weight of bees and the amount of food ($r_s = 0.18$, $p = 0.12$, figure 5).

However, contrary to my prediction, large bees are not limited to particular flower sizes; they can visit also flowers with the alighting place smaller than their own total size. For example all bees that visited *Arenaria congesta* were larger than the alighting place (Appendix 2).

Nevertheless, there is a positive correlation between the height of anthers (distance between pollen and nectar) and the size of thorax + head ($r_s = 0.50$, $p < 0.001$, figure 6). The amount of food (size of anthers multiplied by the number of anthers per flower) and number of species visiting the flowers were positive correlated ($r_s = 0.67$, $p = 0.016$, figure 7), as were the size of the alighting place and number of visitor species ($r_s = 0.66$, $p = 0.019$, figure 8).

Large bees were recorded using flowers with different amount of food, but the flowers that produced more pollen had more individuals and species visiting it (Table 1). The matrix of interaction (Figure 9 B) presented temperature of: 29.25° and nestedness of 0.71 which means that this matrix has a high level of nestedness (figure 9 A).

In the community there are more plants that have easy access (63%, appendix 1) than those that have restricted access to the pollen. Of the plants selected for visitor observation, only one of 12 had the access to pollen classified as difficult.

Discussion

This study shows that most of the floral characteristics do not constrain the use of pollen by bees. When the flowers are evaluated from the nectar perspective the depth and width of tubular structures hiding the nectar are important parameters selecting number of species visiting flowers (Stang 2006). From the pollen perspective the ‘amount of food’ (estimate of pollen quantity) does not restrict any size of bee; nevertheless plants with more food available attract more bee species (Table 1, figure 7). In this work I did not differentiate number of open and closed anthers per flower, but this information would be important to be considered in future studies as some flowers have high number of anthers but not all of them open at the same time.

Large bees also used flowers with different ‘amounts of food’ because bees do not always visit flowers just in search of pollen (Williams & Tepedino 2003) moreover, probably there are other reasons for selecting plants with low pollen amounts e.g., pollen quality, or relative abundance of that species, or low competition, etc. The height of anthers in flowers (distance between pollen and nectar) (figure 6) seems to be an important parameter as 50% of the bees have their size correlated with that ($r_s = 0.50$, $p < 0.001$, figure 6). Probably there is a selective pressure on flowers by bees with appropriate sizes that can promote more pollination, or bees select flowers whose anthers are accessible to them.

If this study had been based just on flower characteristics from the nectar perspective we would exclude *Rosa woodsii* which does not produce nectar; nevertheless this is the plant with the highest number of interactions in the web (Table 1 and figure 9). In studies of communities is important dissecting pollination systems into fractions to facilitate interpretation (Thomson 1983) because of that is important analyse systems with different perspectives when it is possible for example.

The absence of correlation between bee size and flower parameters from the pollen perspective can suggest that bees forage on flowers principally in search of nectar. Apparently there isn’t selection

on plants to match anther height to bee size because when bees are pollen-foraging they are consuming pollen and not transporting it to stigmas.

The interaction between plants and bees in this community presented a nested pattern meaning that there is a core group of generalist species interacting and another group of more specialist species that interact only with a subgroup of the most generalist species (Bascompte *et al.* 2003). In this community the small bees and the flowers with large alighting place are the generalist group. The nestedness value for this community (0.71) is smaller of the average values for most pollination systems (0.844 ± 0.043), nevertheless there are others pollination systems that present values for nestedness smaller than the value presented by the former (see Bascompte *et al.* 2003).

This was the first study examining floral characteristics from the pollen perspective. Most works have been using flower characteristics from the nectar perspective and consequently the morphometric parameters analysed are depth and width of tube and sometimes the alighting place of flowers (Stang 2006, Agosta & Janzen 2005). However, this study showed that the amount of pollen and the height of anthers are also important floral parameters to be analysed. Some floral characteristics do not represent constraints to the bees, but others can facilitate and attract them.

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Appendix 1. Flower size parameters, mean size parameters (based on five flowers per species); the height of the anther is the distance between nectar and pollen; amount of food is the anther size multiplied by number of anthers.

Plant species (plant family)	Number of anthers	Height of anther (mm)	Anther size (mm)	Anther dehiscence	Pollen accessibility	Corolla tube (mm)	Corolla diameter (mm)	Alighting place (mm)	Entrance of corolla (mm)	Inflorescence diameter(mm)	Flowers / inflorescence	Amount of food
<i>Aconiton colombianum</i> (Ranunculaceae)	33	9.23 ± 1.09	0.86 ± 0.24	Longitudi nal	easy	12.22 ± 0.94	8.86 ± 0.32	11.95 ± 0.76	6.08 ± 0.92	0	7.6 ± 3.29	29.97 ± 8.05
<i>Amerosedum lanceolatum</i> (Crassulaceae)	10	8.68 ± 0.96	0.85 ± 0.05	Longitudi nal	easy	4.86 ± 0.61	4.63 ± 0.31	7.16 ± 0.43	4.59 ± 0.71	24.66 ± 3.30	3.8 ± 1.79	8.54 ± 0.47
<i>Arenaria congesta</i> (Caryophyllaceae)	10	7.184 ± 0.67	0.75 ± 0.11	Longitudi nal	easy	4.38 ± 0.47	2.98 ± 0.52	4.70 ± 0.30	2.48 ± 0.38	11.8 ± 2.04	3.2 ± 0.84	7.46 ± 1.07
<i>Calochortus gunnisonii</i> (Calochortaceae)	16.754	9.76 ± 1.39	13.286 ± 2.26	Longitudi nal	easy	13.29 ± 2.18	10.95 ± 5.99	20.59 ± 1.49	20.59 ± 5.99	0	1	58.56 ± 13.57
<i>Campanula rotundifolia</i> (Campanulaceae)	6	11.95 ± 1.12	4.06 ± 0.93	Longitudi nal	easy	11.07 ± 2.17	9.58 ± 1.46	7.36 ± 3.08	8.56 ± 0.64	0		24.34 ± 5.58
<i>Castilleja sulphurea</i> (Scrophulariaceae)	4	18.35 ± 1.44	2.15 ± 0.15	Longitudi nal	difficult	11.93 ± 0.66	2.79 ± 0.51	4.74 ± 0.35	1.75 ± 0.16	18.38 ± 1.82	7.2 ± 1.10	8.6 ± 0.59
<i>Collinsia parviflora</i> (Scrophulariaceae)	4	5.19 ± 0.22	0.455 ± 0.035	Longitudi nal	difficult	5.65 ± 0.48	1.85 ± 0.21	2.9 ± 0.45	0.6 ± 0.10	0	1	1.88 ± 0.23
<i>Cymopterus lemmonii</i> (Apiaceae)	5	2.42 ± 0.26	0.56 ± 0.05	Longitudi nal	easy	1.22 ± 0.13	1.35 ± 0.17	32.82 ± 2.92	1.35 ± 0.17	32.82 ± 2.92	28.6 ± 9.37	2.81 ± 0.25
<i>Delphinium nuttallianum</i> (Primulaceae)	35.6 ± 2.88	6.42 ± 0.42	0.81 ± 0.08	Longitudi nal	difficult	15.92 ± 2.02	3.04 ± 0.19	6.36 ± 0.23	2.19 ± 0.30	0	1	28.74 ± 2.53
<i>Dodecatheon pulchellum</i> (Primulaceae)	5	8.56 ± 0.90	6.79 ± 0.33	Poricidal	easy	0	3.04 ± 0.36	3.04 ± 0.36	3.04 ± 0.36	0	1	33.96 ± 1.67
<i>Draba aurea</i> (Brassicaceae)	6	6.5 ± 1.88	1.078 ± 0.24	Longitudi nal	easy	4.93 ± 1.14	2.15 ± 0.29	3.00 ± 0.82	2.15 ± 0.29	17.04 ± 2.55	13 ± 4.69	6.47 ± 1.42
<i>Erigeron flagellaris</i> (Asteraceae)	5	2.71 ± 0.24	1.59 ± 0.29	Longitudi nal	easy	2.55 ± 0.25	0.99 ± 0.09	6.93 ± 1.13	0.98 ± 0.08	18.57 ± 3.07	18.4 ± 4.34	7.97 ± 1.45
<i>Eriogonum umbellatum</i> (Polygonaceae)	9	4.75 ± 1.19	0.72 ± 0.35	Longitudi nal	easy	3.76 ± 0.24	4.01 ± 0.28	25.09 ± 3.39	4.01 ± 0.28	25.09 ± 3.39	122.5 ± 36.06	6.48 ± 3.18
<i>Erysimum capitatum</i> (Brassicaceae)	6	13.55 ± 1.64	3.27 ± 1.30	Longitudi nal	easy	12.35 ± 1.24	2.49 ± 0.38	8.05 ± 1.85	2.27 ± 0.71	33.09	10.6 ± 2.88	19.63 ± 7.78
<i>Galium septentrionale</i> (Rubiaceae)	4	0.9 ± 0.05	0.26 ± 0.04	Longitudi nal	easy	0	0.7 ± 0.13	2.10 ± 0.23	5.17 ± 0.20	11.13 ± 2.24	15.6 ± 6.80	1.03 ± 0.16
<i>Helianthella quinquenervis</i> (Asteraceae)	5	6.51 ± 0.93	3.50 ± 0.25	Longitudi nal	easy	4.25 ± 0.19	1.43 ± 0.22	18.79 ± 2.67	1.43 ± 0.22	71.96 ± 8.39	47.2 ± 19.80	17.49 ± 1.27
<i>Linaria vulgaris</i> (Scrophulariaceae)	4	10.78 ± 0.51	1.34 ± 0.11	Longitudi nal	difficult	15.23 ± 2.28	3.4 ± 0.33	8.80 ± 0.59	5.62 ± 0.51	0	11.8 ± 1.30	5.36 ± 0.45
<i>Linum lewissii</i> (Linaceae)	5	10.93 ± 1.06	1.97 ± 0.08	Longitudi nal	easy	0	4.38 ± 0.55	18.24 ± 0.61	23.12 ± 5.47	0	1	9.84 ± 0.42
<i>Mertensia ciliata</i> (Boraginaceae)	5	9.91 ± 0.35	2.19 ± 0.20	Longitudi nal	easy	15.23 ± 0.73	3.54 ± 0.24	6.48 ± 0.99	6.48 ± 0.99	0	1	10.97 ± 1.02
<i>Potentilla fruticosa</i> (Rosaceae)	24.2 ± 2.77	2.09 ± 0.56	1.27 ± 0.12	Longitudi nal	easy	0	22.45 ± 2.56	9.06 ± 0.88	22.45 ± 2.56	0	1	27.2 ± 1.97

<i>Potentilla gracilis</i> (Rosaceae)	20	3.95 ± 0.63	0.99 ± 0.17	Longitudi nal	easy	0	16.70 ± 1.30	8.64 ± 0.72	16.70 ± 1.30	0	1	19.72 ± 3.41
<i>Pyrrocroma crocea</i> (Asteraceae)	5	10.89 ± 0.97	3.49 ± 0.36	Longitudi nal	easy	9.22 ± 0.50	1.30 ± 0.07	17.45 ± 2.56	1.72 ± 0.14	55.78 ± 11.46	45.8 ± 36.11	17.46 ± 1.81
<i>Rosa woodsii</i> (Rosaceae)	113 ± 9.46	6.65 ± 1.21	2.39 ± 0.27	Longitudi nal	easy	0	41.14 ± 1.67	21.27 ± 0.54	41.14 ± 1.67	0	1	268.83 ± 19.71
<i>Senecio serra</i> (Asteraceae)	5	5.72 ± 0.70	2.796 ± 0.46	Longitudi nal	easy	4.87 ± 0.33	1.34 ± 0.09	6.23 ± 0.94	1.34 ± 0.09	6.23 ± 0.94	45	13.98 ± 2.31
<i>Senecio atratus</i> (Asteraceae)	5	3.89 ± 0.68	1.95 ± 0.63	Longitudi nal	easy	3.62 ± 0.44	0.96 ± 0.12	5.06 ± 0.51	0.96 ± 0.12	15.95 ± 1.34	47 ± 6.59	9.73 ± 3.15
<i>Trifolium repens</i> (Fabaceae)	10	4.14 ± 0.16	0.32 ± 0.02	Longitudi nal	difficult	3.54 ± 0.46	1.45 ± 0.15	5.60 ± 0.19	0.99 ± 0.16	19.69 ± 2.86	9.6 ± 4.22	3.2 ± 0.19
<i>Zigadenus elegans</i> (Fabaceae)	6	6.69 ± 0.42	1.23 ± 0.30	Longitudi nal	easy	0	7.24 ± 0.85	5.16 ± 0.91	7.24 ± 0.85	0	1	7.57 ± 1.81

Appendix 2. Bee size parameters and plant species the bee was visiting

Bee species	Body weight (g)	Total length (mm)	Abdomen (mm)	Thorax (mm)	Head (mm)	Thorax + Head (mm)	Plant species visited
<i>Dialictus</i> sp	0.005	6.77	2.88	1.7	1.64	3.34	<i>Erigeron flagellaris</i>
<i>Osmia</i> sp2	0.045	10.06	4.87	3.37	2.83	6.2	<i>Senecio serra</i>
<i>Evylaeus</i> sp	0.008	2.24	3.54	2.17	1.84	4.01	<i>Draba aurea</i>
<i>Dialictus</i> sp	0.003	5.46	2.74	1.44	1.34	2.78	<i>Cymopterus lemmonii</i>
<i>Dialictus</i> sp	0.003	5.46	2.74	1.44	1.34	2.78	<i>Erigeron flagellaris</i>
<i>Dialictus</i> sp	0.003	6.38	3.69	2.19	1.39	3.58	<i>Erigeron flagellaris</i>
<i>Dialictus</i> sp	0.006	6.04	2.73	1.75	1.57	3.32	<i>Erigeron flagellaris</i>
<i>Dialictus</i> sp	0.005	5.83	2.9	1.8	1.52	3.32	<i>Draba aurea</i>
<i>Dialictus</i> sp	0.003	4.68	2.34	1.34	1.04	2.38	<i>Erigeron flagellaris</i>
<i>Dialictus</i> sp	0.007	5.94	3	1.89	1.3	3.19	<i>Erigeron flagellaris</i>
<i>Panurginae</i>	0.007	2.28	3.58	2.06	1.65	3.71	<i>Potentilla fruticosa</i>
<i>Hoplitis robusta</i>	0.015	7.78	3.23	2.04	2.05	4.09	<i>Potentilla gracilis</i>
<i>Panurginae</i>	0.01	7.02	3.81	2.21	1.53	3.74	<i>Potentilla gracilis</i>
<i>Dialictus</i> sp	0.005	6.16	2.98	1.71	1.31	3.02	<i>Potentilla gracilis</i>
<i>Dialictus</i> sp	0.005	6.15	3.22	1.63	1.3	2.93	<i>Potentilla gracilis</i>
<i>Dialictus</i> sp	0.003	4.58	2.69	1.4	1.03	2.43	<i>Cymopterus lemmonii</i>
<i>Dialictus</i> sp	0.007	6.03	3.1	1.79	1.32	3.11	<i>Cymopterus lemmonii</i>
<i>Megachile</i> sp2	0.033	9.99	4.25	3.06	2.5	5.56	<i>Erigeron flagellaris</i>
<i>Evylaeu</i> sp s	0.011	7.86	3.69	2.18	1.93	4.11	<i>Erysimum capitatum</i>
<i>Dialictus</i> sp	0.004	5.18	2.56	1.69	1.34	3.03	<i>Erigeron flagellaris</i>
<i>Dialictus</i> sp	0.003	5.8	2.79	1.57	1.37	2.94	<i>Potentilla fruticosa</i>
<i>Dialictus</i> sp	0.004	5.93	2.74	1.78	1.47	3.25	<i>Cymopterus lemmonii</i>
<i>Dialictus</i> sp	0.004	5.27	2.47	1.65	1.26	2.91	<i>Cymopterus lemmonii</i>
<i>Dialictus</i> sp	0.005	5.87	2.65	1.83	1.4	3.23	<i>Cymopterus lemmonii</i>
Sp	0.005	6.34	3.33	1.71	1.57	3.28	<i>Erigeron flagellaris</i>
<i>Dialictus</i> sp	0.005	6.48	3.41	1.82	1.4	3.22	<i>Potentilla fruticosa</i>
<i>Dialictus</i> sp	0.004	6.15	2.92	1.67	1.52	3.19	<i>Erysimum capitayum</i>
<i>Dialictus</i> sp	0.003	5.26	2.98	1.34	1.25	2.59	<i>Erigeron flagellaris</i>
<i>Osmia</i> sp2	0.046	9.29	3.97	2.99	2.73	5.72	<i>Senecio serra</i>
<i>Dialictus</i> sp	0.003	6.24	2.78	1.7	1.39	3.09	<i>Senecio serra</i>
<i>Andrena</i> sp3	0.027	10.34	6.19	3.39	2.08	5.47	<i>Potentilla fruticosa</i>
<i>Megachile</i> sp2	0.048	9.8	4.57	3.19	2.78	5.97	<i>Erigeron flagellaris</i>
<i>Osmia</i>	0.074	14.68	6.25	3.72	3.37	7.09	<i>Helianthella</i>

(<i>Cephalosmia</i> <i>Montana</i>)							<i>quinquenervis</i>
<i>Bombus bifarius</i>	0.077	9.82	5.65	3.77	3.03	6.8	<i>Helianthella</i>
<i>Dialictus</i> sp	0.005	6.44	3.4	1.59	1.41	3	<i>quinquenervis</i>
<i>Colletes</i> sp	0.018	7.27	3.76	2.61	2.21	4.82	<i>Potentilla gracilis</i>
<i>Megachile</i> sp2	0.051	11.89	5.64	3.45	3.1	6.55	<i>Linum lewissii</i>
<i>Osmia</i> sp3	0.045	9.79	4.49	3.17	3.04	6.21	<i>Linum lewissii</i>
<i>Dufourea</i> cf	0.004	6.26	3.78	2.03	1.32	3.35	<i>Potentilla gracilis</i>
<i>Panurginae</i>	0.006	6.78	3.61	2.23	1.43	3.66	<i>Potentilla gracilis</i>
<i>Hoplitis fulgida</i>	0.01	7.42	3.42	2.13	1.87	4	<i>Potentilla gracilis</i>
<i>Bombus</i> <i>flavifrons</i>	0.347	16.81	9.86	6.41	5.23	11.64	<i>Helianthella</i>
<i>Bombus</i> <i>flavifrons</i>	0.098	10.5	4.96	4.69	3.17	7.86	<i>quinquenervis</i>
<i>Panurginae</i>	0.006	6.65	3.56	2.03	1.27	3.3	<i>Castilleja</i> <i>sulphurea</i>
<i>Hylaeus</i> sp	0.012	6.25	3.17	2.61	1.73	4.34	<i>Cymopterus</i> <i>lemmonii</i>
<i>Panurginae</i>	0.006	6.06	3.5	2.05	1.21	3.26	<i>Potentilla gracilis</i>
<i>Hoplitis robusta</i>	0.013	6.86	3.18	2.42	2.65	5.07	<i>Potentilla gracilis</i>
<i>Panurginae</i>	0.007	6.63	4.09	1.84	1.36	3.2	<i>Potentilla gracilis</i>
<i>Andrena</i> sp2	0.045	10.79	6.11	3.26	2.69	5.95	<i>Potentilla gracilis</i>
<i>Osmia</i> sp1	0.044	9.45	4.4	3.49	3.15	6.64	<i>Potentilla gracilis</i>
<i>Hylaeus</i> sp	0.009	6.19	2.86	2.44	1.65	4.09	<i>Linum lewissii</i>
<i>Bombus</i> <i>flavifrons</i>	0.229	16.69	8.02	5.52	4.57	10.09	<i>Helianthella</i>
<i>Osmia bucephala</i>	0.119	14.3	6.31	4.44	5.03	9.47	<i>quinquenervis</i>
<i>Osmia bucephala</i>	0.164	16.58	7.6	5.26	4.75	10.01	<i>Helianthella</i>
<i>Panurginae</i>	0.005	6.89	3.56	1.83	1.33	3.16	<i>quinquenervis</i>
<i>Bombus bifarius</i>	0.107	12.42	5.74	4.23	3.29	7.52	<i>Linum lewissii</i>
<i>Andrena</i> sp1	0.049	13.92	7.74	4.07	3.08	7.15	<i>Rosa woodsii</i>
<i>Bombus bifarius</i>	0.098	12.42	5.73	3.82	3.08	6.9	<i>Arenaria congesta</i>
<i>Hoplitis robusta</i>	0.012	6.76	2.86	2.2	2.17	4.37	<i>Arenaria congesta</i>
<i>Hylaeus basalis</i>	0.019	8.92	5.08	2.76	2.06	4.82	<i>Linum lewissii</i>
<i>Bombus bifarius</i>	0.294	15.18	8.93	5.74	4.37	10.11	<i>Rosa woodsii</i>
<i>Hoplitis robusta</i>	0.012	6.01	2.82	2.13	2.25	4.38	<i>Rosa woodsii</i>
<i>Evylaeus</i>	0.009	6.65	3.28	2.01	1.46	3.47	<i>Rosa woodsii</i>
<i>Hoplitis fulgida</i>	0.03	8.03	4.08	3.06	2.6	5.66	<i>Rosa woodsii</i>
<i>Hylaeus basalis</i>	0.022	7.34	4.25	2.96	1.79	4.75	<i>Rosa woodsii</i>
<i>Panurginae</i>	0.007	7.18	3.62	1.97	1.63	3.6	<i>Rosa woodsii</i>
<i>Hylaeus</i> sp	0.007	6.01	2.84	2.1	1.47	3.57	<i>Rosa woodsii</i>
<i>Panurginae</i>	0.009	6.93	3.88	2.14	1.29	3.43	<i>Rosa woodsii</i>
<i>Osmia bucephala</i>	0.105	12.63	5.73	4.63	3.83	8.46	<i>Rosa woodsii</i>
<i>Hylaeus</i> sp	0.008	7.04	3.42	1.8	1.53	3.33	<i>Rosa woodsii</i>
<i>Hylaeus</i> sp	0.005	6.16	2.95	2.16	1.53	3.69	<i>Rosa woodsii</i>
<i>Dialictus</i>	0.005	5.9	3.04	1.97	1.28	3.25	<i>Rosa woodsii</i>
<i>Dialictus</i>	0.004	4.82	2.56	1.52	0.78	2.3	<i>Potentilla gracilis</i>
<i>Megachile</i> sp1	0.137	14.96	7.36	4.62	3.95	8.57	<i>Helianthella</i>
<i>Bombus</i> <i>flavifrons</i>	0.086	10.78	5.15	4.42	3.11	7.53	<i>quinquenervis</i>
							<i>Castilleja</i> <i>sulphurea</i>

Table 1. Plant species monitored and number of bee species and individuals recorded visiting the flowers.

Plant specie	Bee species / number of individuals
<i>Rosa woodsii</i>	9 (14)
<i>Potentilla gracilis</i>	8 (15)
<i>Helianthella quinquenervis</i>	5 (6)
<i>Linum lewissii</i>	5 (6)
<i>Potentilla fruticosa</i>	3 (4)
<i>Arenaria congesta</i>	2 (3)
<i>Erigeron flagellaris</i>	2 (11)
<i>Cymopterus lemmonii</i>	2 (7)
<i>Draba aurea</i>	2 (2)
<i>Erysimum capitayum</i>	2 (2)
<i>Senecio serra</i>	2 (3)
<i>Castilleja sulphurea</i>	1 (2)

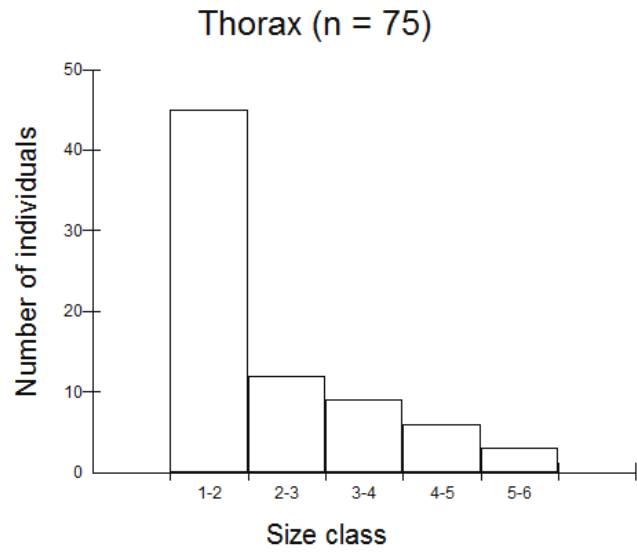
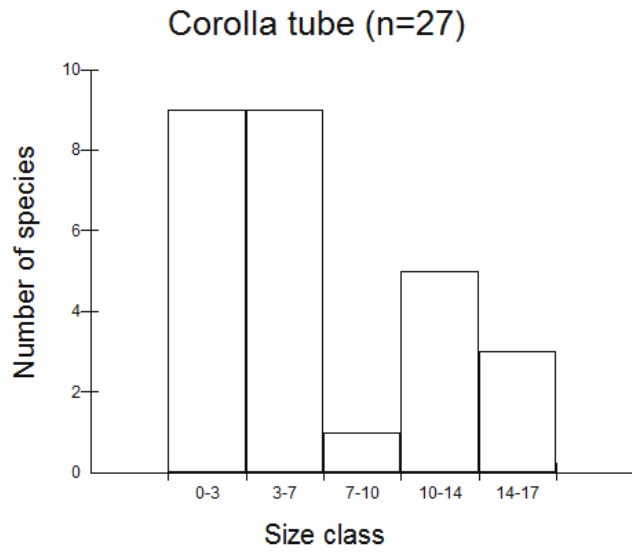


Figure 1- Flowers' parameters size distribution from the community.

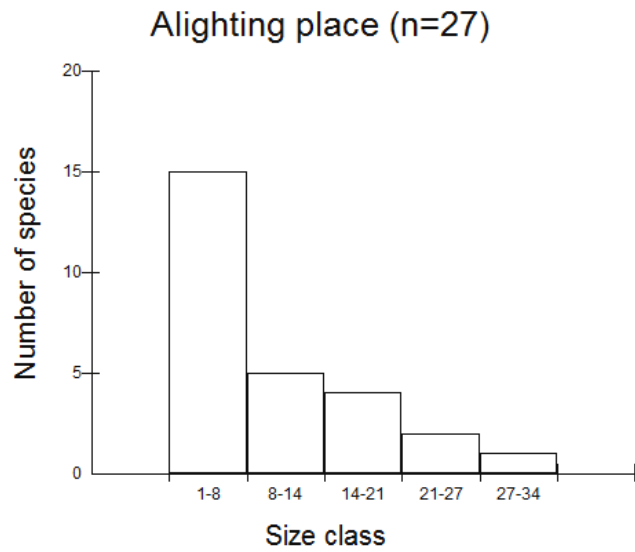
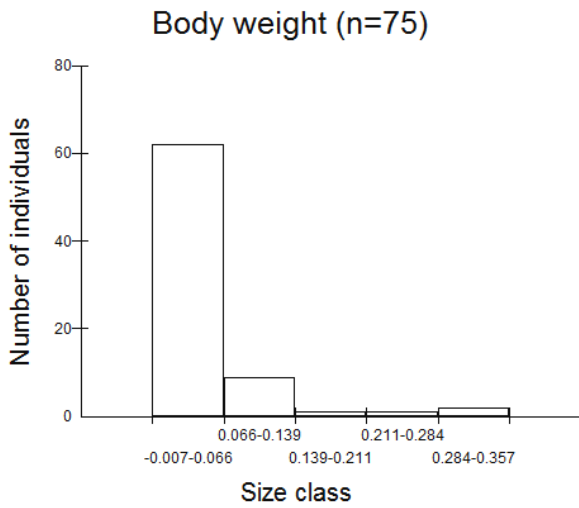


Figure 2- Individuals' body size distributions of bees from the '401' area in RMBL.

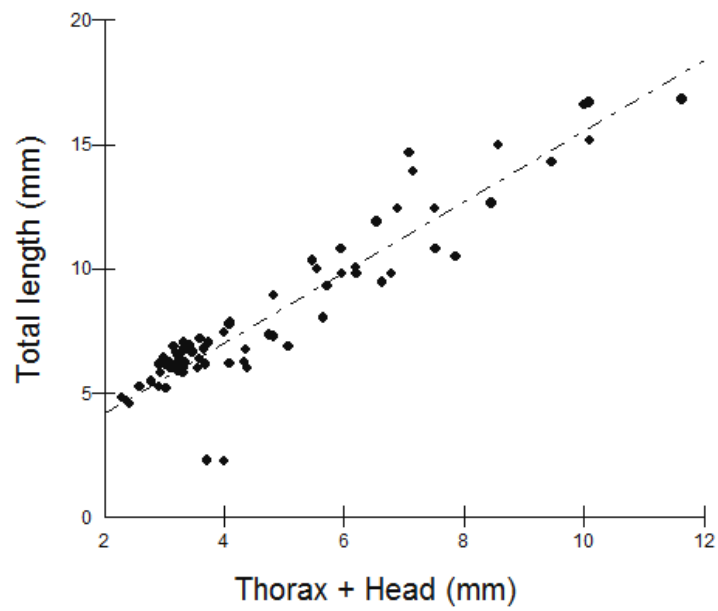


Figure 3- Relationship between total length and thorax head

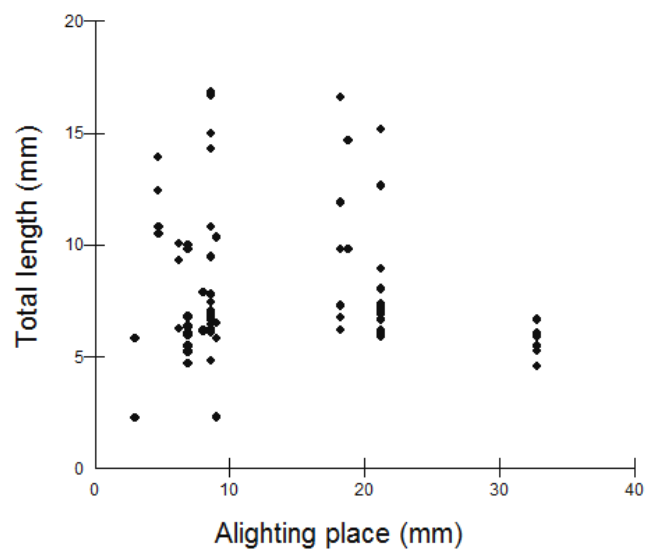


Figure 4. Relationship between total length of bees and size of alighting place

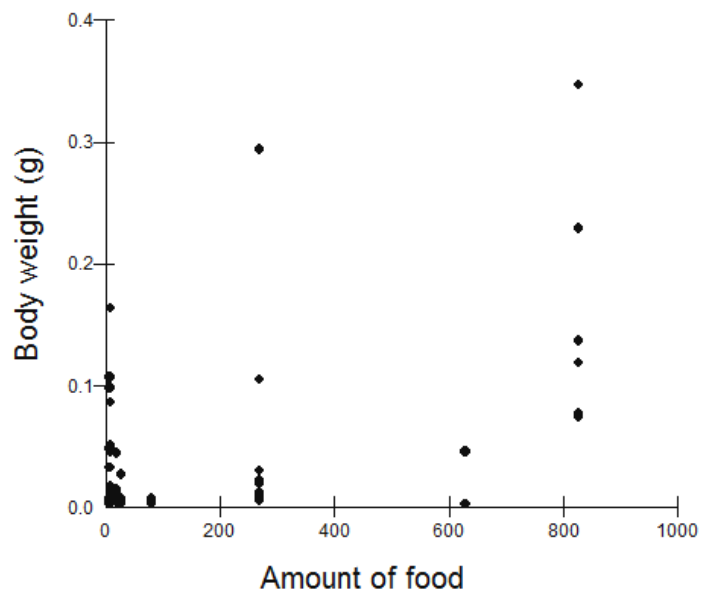


Figure 5. Relationship between weight and amount of food

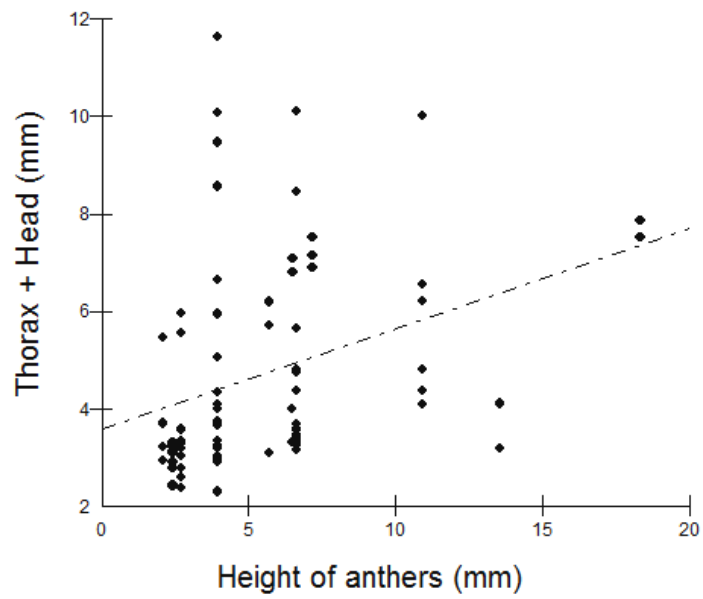


Figure 6. Relationship between thorax + head and height of anthers (distance between pollen and nectar).

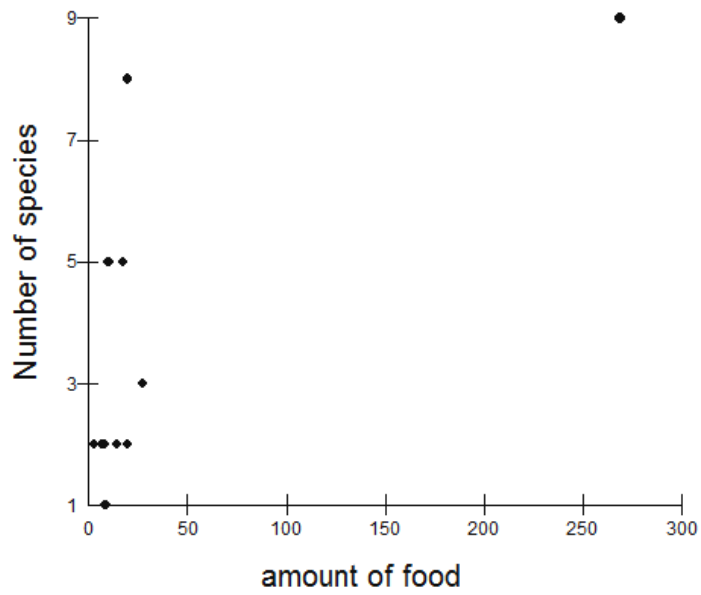


Figure 7. Relationship between number of species and amount of food (number of anthers multiplied per size of anthers).

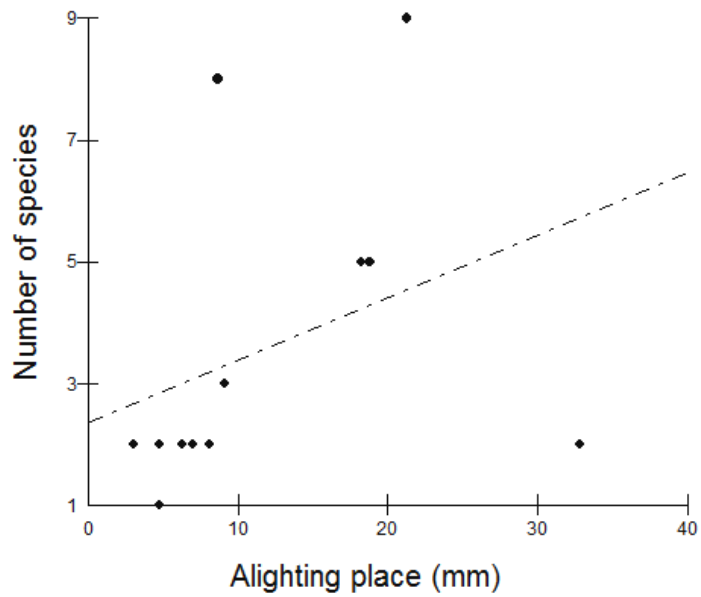
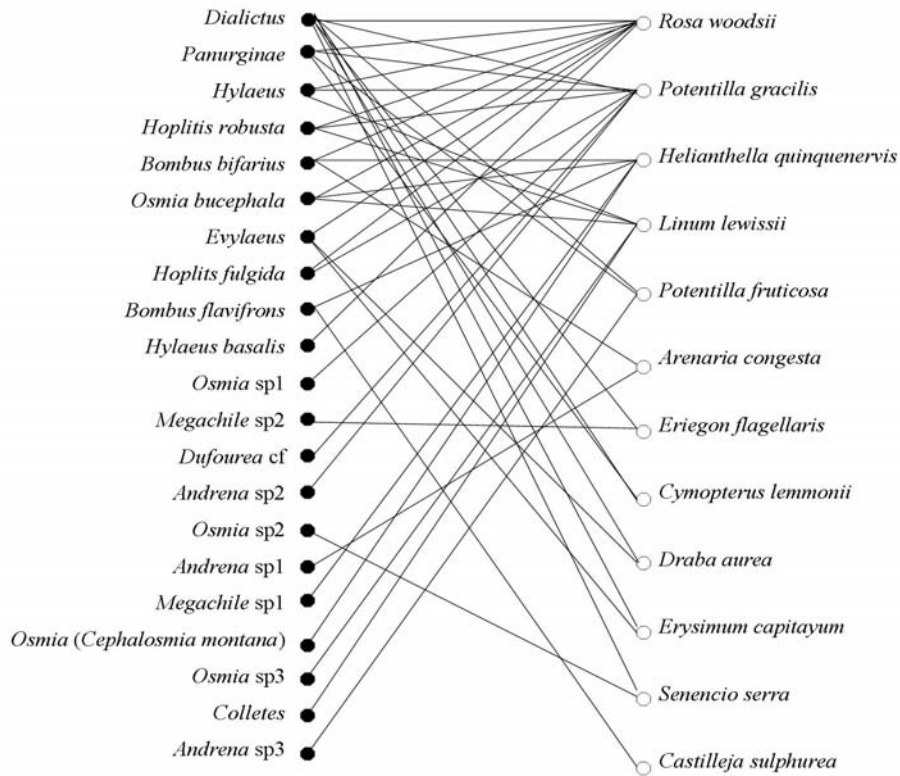


Figure 8. Relationship between number of species and alighting place.

A



B

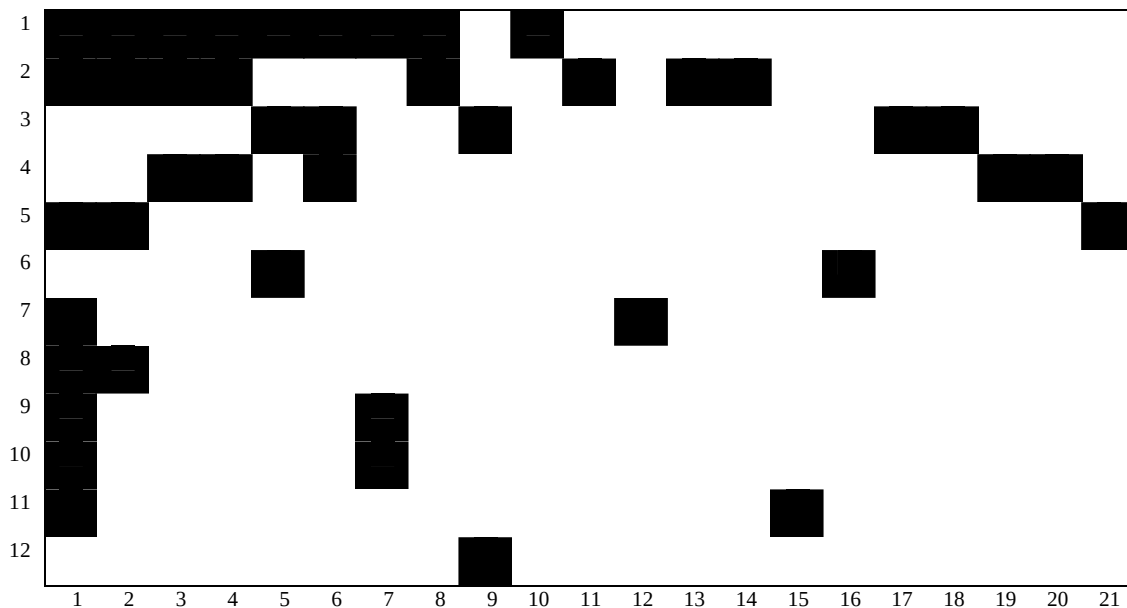


Figure 9. Network (A) and matrix (B) of interaction from the community of plants (empty circles and lines) and bees (black circles and columns). The data are binary and lines between a pair of species as well as spaces filled by black squares represent interactions. The numerical sequence in line (plants) and columns (bees) of the matrix represent the species present in the network following the sequence of species from the top (species with more interactions) to the base (species with fewer interactions) from the network.