

Impact of Resource Availability on Bee Diversity

by

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ABSTRACT

Resource availability is an important predictor of abundance and species richness. In this paper we verified why there is local variation in bee diversity testing the hypothesis that bee species richness and abundance will increase with increasing resource availability. Resource availability was considered here as the number of flowering plants and the number of plant species. Sampling was carried out at two sites in Brazil, the quartzitic range (Ouro Branco) and metaliferous fields (Ouro Preto). At these sites ecosystems are endangered by high anthropogenic impacts, particularly due to mining and urbanization. The samples were collected for 10 months in each site, twice a month, from 8:00 am to 5:00 pm. The bees belonged to 77 species and 5 subfamilies. Bee species and abundance increased with the increase in the number of plant species and plant abundance at both sites. Bee richness and abundance were higher in Ouro Branco than in Ouro Preto. Our results showed that bee diversity may be regulated by resource availability.

Key words: abundance, Apidae, resource, species richness.

INTRODUCTION

The abundance and spatio-temporal predictability of resources are recognized as important factors impairing resource usage by animals. Resource heterogeneity and amount can modulate species interactions determining richness (Cornell & Lawton 1992). The habitat heterogeneity hypothesis assumes that structurally complex habitats may provide more niches and thus increase diversity by permitting species co-occurrence (Tilman & Pacala 1993). Abundance and species richness can also increase with available energy because areas richer in food resources should support more individuals and so greater species populations (Srivastava & Lawton 1998).

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In several habitats, plant communities may determine the availability of resources and provide the physical structure of the environment. So plant communities have considerable influence on the distributions and interactions of animal taxa. In the case of bees, resources are provided by flowering plants that attract pollinators. Nectar and pollen feeders, especially bees, are often affected by interspecific competition for high-quality food resources (Schaffer *et al.* 1979; Sudgen *et al.* 1996).

In recent years, the general decline in the number of wild bees has been due to disrupted natural habitats (Bortoli & Laroca 1997; Zanette *et al.* 2005). With this in mind in this paper we analysed two habitats with different disturbance level, testing the hypothesis that bee species richness and abundance will increase with increases in resource availability. Because different plant species have distinct pollen and nectar rewards, both in terms of quantity and quality (e.g. Chittka *et al.* 1999) we used here the number and richness of flowering plants as a surrogate for resource availability for bee communities.

MATERIALS AND METHODS

Study site

We studied two different ecosystems in the southern Espinhaço Range in Minas Gerais state, Brazil. These sites were in the iron stone fields (locally know as Canga) and the rupestrian fields in the Ouro Branco Mountains.

The Canga area is located at the Ouro Preto municipality (43°30' and 43°31'W; 20°23' and 20°24'S). The mountain peak in the area is approximately 1230 m. From 1940 to 1950, the region, which is formed by a rigid-substrate iron compound, was mined for bauxite. Grasses (20-50cm tall) completely cover the substrate and several Asteraceae, Malpighiaceae, Myrtaceae, Verbenaceae, and other species can also be found.

The Ouro Branco fields, located at the Ouro Branco municipality (43°46' and 43°33'W; 20°26' and 20°30'S), occupy approximately 65 km², maximum altitude 1573 m. The mountains' quartzitic surface rocks are mainly covered by low-mountain pluvial forests and riparia, and also by quartzitic and ferruginous fields (Alckmim 1987).

Bee and plant sampling

Bees were sampled from October 2001 to July 2002 in Canga area and from October 2002 to July 2003 at the Ouro Branco fields from 8:00 to 17:00. Sampling was carried out every 15 days in different transects of 2500m by two collectors. Each transect was evaluated twice a month, totaling 10 transects per site. A minimum distance of 100m was maintained between transects. Each collector remained at a flowering plant for five minutes.

The bees were trapped in entomological nets as soon as they landed on or right after leaving the flowers. The bees were placed in a lethal vial and were killed; next, they were mounted with entomological pins and identified to the highest taxonomic level possible. Voucher specimens were deposited at the entomological collection of the Universidade Federal de Ouro Preto (UFOP), Ouro Preto, MG. Although the species *Apis mellifera* L. was abundant and its occurrence registered, we did not capture all individuals.

Inside each transect, two samples of each flowering plant species were collected for identification and herborization. Some of the fertile material was first herborized and then deposited at the Herbário Professor José Badini, Universidade Federal de Ouro Preto.

Statistical analysis

For the analysis we considered the total number of bee species and number of bees sampled in each transect. To investigate the relationship between bee species richness and bee abundance with the number of plant species and the number of flowering plants we performed different analyses of covariance (ANCOVA). Bee species richness and bee abundance were the response variables and the explanatory variables were the number of flowering plant species or the number of flowering plants (x_1 variables) and sampling site (x_2).

All the analyses were carried out using generalized linear modeling (Crawley 2002) and Poisson errors and were performed under R (R Development core Team 2005). We use residual analyses to verify error distribution and the suitability of the models employed, including checks for over-dispersion.

RESULTS

Bee specimens collected comprised 77 species and five subfamilies. We collected 66 bee species in Ouro Branco and 27 in Ouro Preto, 15 of which

Table 1. Bee species sampled in Ouro Preto (OP, from October 2001 to July 2002) and Ouro Branco (OB, from October 2002 to July 2003), Minas Gerais state, Brazil.

Species or morphospecies	OP	OB
ANDRENINAE		
<i>Oxaea flavescens</i> Klug	X	
APINAE		
<i>Anthophora paranensis</i> Holmberg	X	
<i>Apis mellifera</i> L.	X	X
<i>Arhysoceble</i> sp. 1		X
<i>Bombus (Fervidobombus) atratus</i> Franklin	X	X
<i>Bombus (Fervidobombus) brasiliensis</i> Lepeletier	X	
<i>Bombus (Fervidobombus) morio</i> Swederus	X	X
<i>Centris (Paracentris) klugi</i> Friese		X
<i>Centris (Ptilotopus) scopipes</i> Friese		X
<i>Centris (Xanthemisia) bicolor</i> Lepeletier	X	X
<i>Centris (Xanthemisia) sp. 1</i>		X
<i>Centris (Centris s. str.) aenea</i> Lepeletier	X	X
<i>Centris (Centris s. str.) varia</i> Erichson	X	X
<i>Centris (Hemisiella) tarsata</i> Smith		X
<i>Centris (Trachina) fuscata</i> Lepeletier		X
<i>Centris</i> sp.1	X	X
<i>Ceratina (Ceratinula) sp. 1</i>		X
<i>Ceratina</i> sp. 1		X
<i>Ceratina</i> sp. 2	X	X
<i>Epicharis</i> sp. 1	X	
<i>Epicharis</i> sp. 2	X	
<i>Epicharis (Anepicharis) dejeanii</i> Lepeletier		X
<i>Epicharis (Epicharana) flava</i> Friese		X
<i>Epicharis (Epicharoides) grandior</i> Friese		X
<i>Epicharis (Triepicharis) schrottkyi</i> Friese		X
<i>Epicharis (Cyphepicharis) sp. 1</i>		X
<i>Euglossa</i> sp. 1		X
<i>Eulaema (Apeulaema) nigrita</i> Lepeletier	X	X
<i>Exomalopsis (Exomalopsis) auropilosa</i> Spinola		X
<i>Exomalopsis</i> sp. 1	X	X

Table 1. Bee species sampled in Ouro Preto (OP, from October 2001 to July 2002) and Ouro Branco (OB, from October 2002 to July 2003), Minas Gerais state, Brazil (continued).

Species or morphospecies	OP	OB
<i>Exomalopsis</i> sp. 2	X	
<i>Exomalopsis</i> sp. 3	X	
<i>Geotrigona</i> sp. 1		X
<i>Geotrigona</i> sp. 2		X
<i>Geotrigona</i> sp. 3		X
<i>Melipona (Eomalipona) bicolor</i> Lepeletier		X
APINAE		
<i>Melipona (Melikerria) quinquefasciata</i> Lepeletier	X	X
<i>Melipona (Melipona) quadrifasciata</i> Lepeletier	X	
<i>Melitoma segmentaria</i> Fabricius		X
<i>Melissoptila cnecomola</i> Friesex	X	
<i>Monoeca</i> sp. 1		X
<i>Monoeca</i> sp. 2		X
<i>Monoeca</i> sp. 3		X
<i>Paratetrapedia</i> sp. 1	X	X
<i>Paratrigona lineata</i> Lepeletier		X
<i>Paratrigona subnuda</i> Moure		X
<i>Tapinotaspoides</i> sp. 1		X
<i>Tetrapedia</i> sp. 1		X
<i>Tetrapedia</i> sp. 2		X
<i>Tetrapedia</i> sp. 3		X
<i>Tetrapedia</i> sp. 4		X
<i>Thygater</i> sp. 1		X
<i>Thygater analis</i> Lepeletier	X	X
<i>Trigona</i> sp. 1		X
<i>Trigona hyalinata</i> Lepeletier		X
<i>Trigona spnipes</i> Fabricius	X	X
<i>Xylocopa</i> sp. 1		X
<i>Xylocopa (Dasxylocopa)</i> sp. 1		X
<i>Xylocopa (Stenoxycopa)</i> sp. 1		X
COLLETINAE		
<i>Tetraglossula</i> sp. 1		X

Table 1. Bee species sampled in Ouro Preto (OP, from October 2001 to July 2002) and Ouro Branco (OB, from October 2002 to July 2003), Minas Gerais state, Brazil (continued).

Species or morphospecies	OP	OB
HALICTINAE		
<i>Augochloropsis</i> sp. 1	X	X
<i>Augochloropsis</i> sp. 2		X
<i>Augochloropsis</i> sp. 3		X
<i>Augochloropsis</i> sp. 4		X
<i>Augochloropsis</i> sp. 5		X
<i>Augochloropsis</i> sp. 6		X
<i>Dialictus</i> sp. 1		X
<i>Dialictus</i> sp. 2		X
<i>Dialictus</i> sp. 3		X
<i>Pseudagapostemon brasiliensis</i> Cure		X
<i>Pseudagapostemon</i> sp. 1		X
<i>Pseudaugochlora</i> sp. 1		X
<i>Pseudaugochlora graminea</i> Fabricius	X	X
MEGACHILINAE		
<i>Megachile (Neochelynia)</i> sp.		X
<i>Megachile (Leptorachis)</i> sp	X	
<i>Megachile</i> sp. 1	X	
<i>Megachile</i> sp. 2		X
TOTAL	27 spp	66 spp

occurred at both sites. Fifty species occurred only in Ouro Branco and 11 in Ouro Preto (Table 1).

Bee species richness presented a positive relationship with the number of flowering plant species ($\chi^2_{17,19} = 13.037$ and $P < 0.001$, Fig. 1). Bee abundance was also positively related to the number of flowering plant species at both sites ($\chi^2_{17,19} = 26.083$ and $P < 0.001$, Figs. 1 and 2). However, bee species number ($\chi^2_{17,19} = 31.476$ and $P < 0.001$) and abundance ($\chi^2_{17,19} = 56.562$ and $P < 0.001$) showed significant differences between sites (Figs. 1 and 2).

The effect of plant abundance on bee species richness and number of bees showed the same pattern. Bee species richness showed a positive relationship

with the number of flowering plants ($\chi^2_{17,19} = 4.050$ and $P = 0.044$, Fig. 3). Bee abundance also increased with increases in flowering plant abundance ($\chi^2_{17,19} = 14.087$ and $P < 0.001$, Fig. 4). Both bee species ($\chi^2_{17,19} = 21.114$ and $P < 0.001$) and abundance ($\chi^2_{17,19} = 36.695$ and $P < 0.001$) showed significant differences between sites (Figs. 3 and 4).

DISCUSSION

Our results showed that abundance and local bee species richness respond positively to availability of resources in the two sites sampled. This positive relationship between bee diversity and resource availability could be related to bee foraging strategies and also to the number of niches offered. Animals

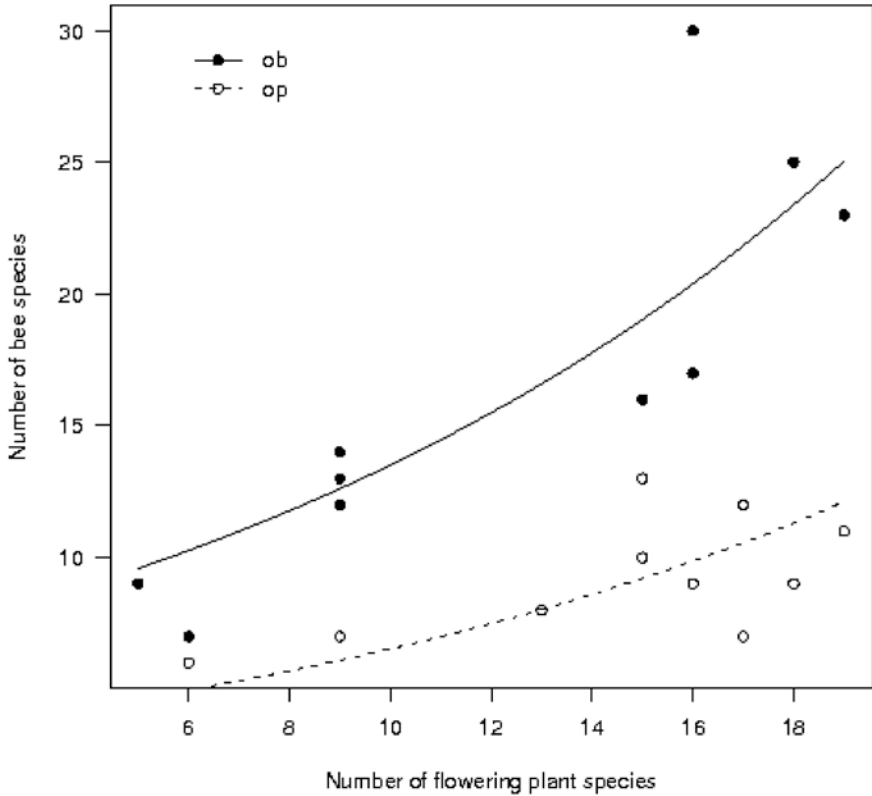


Fig. 1. Relationship between the number of flowering plant species and bee species richness. OB = Ouro Branco and OP = Ouro Preto, Brazil, Minas Gerais state.

that have the ability to discern patch quality during foraging can minimize energy during the search and maximize resource acquisition. Specifically, bees are known to be sensitive to resource availability (Michener 2000; Potts *et al.* 2003) and exhibit a complex social behaviour which permits efficient food exploitation. Social bees have efficient communication systems and are known to be sensitive to information on food availability in and outside nests (Hofstede & Sommeijer 2006). So foraging behavior may change in response to floral resource availability in both quantity of flowers and floral reward structure (nectar and pollen) (Klein *et al.* 2004; Potts *et al.* 2004). Moreover, many solitary bees visit a restricted number of closely related plant species and are temporally and spatially limited in distribution to the occurrence of their host plants. So bees could select those patches that have greater resources to

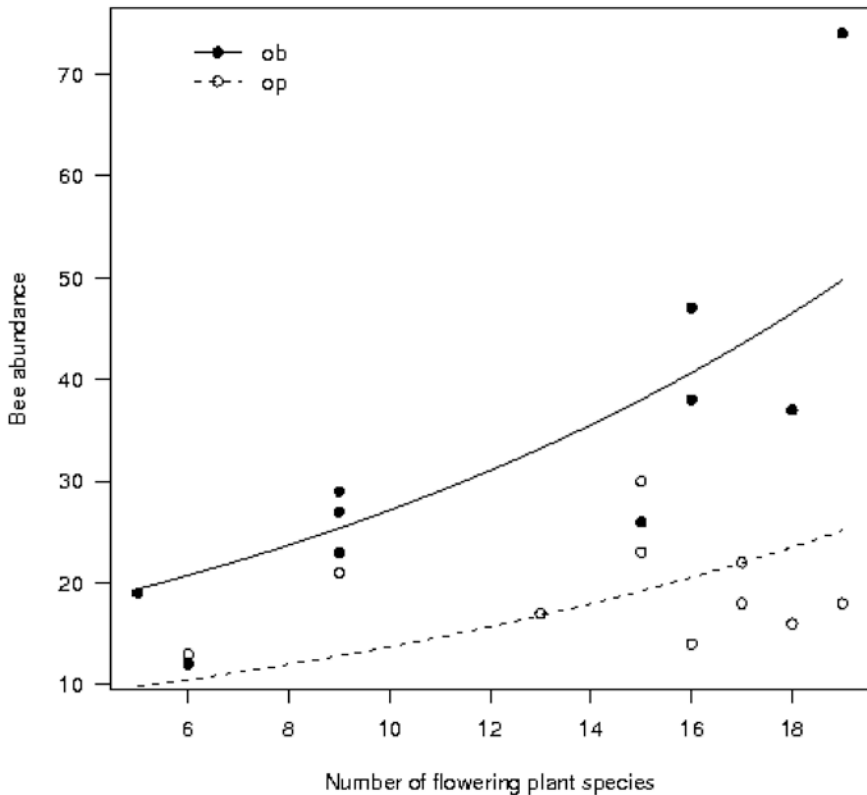


Fig. 2. Relationship between the number of flowering plant species and bee abundance. OB = Ouro Branco and OP = Ouro Preto. Brazil, Minas Gerais state.

offer, which explains the positive correlation between resource availability and bee diversity.

Moreover, the pattern found here could also be related to increases in available food or nesting sites in habitats of greater resource availability. A positive relationship between plant species richness and bee activity has been reported (Klein *et al.* 2003a,b; Potts *et al.* 2003,2004; Ricketts 2004), showing that high plant diversity can support a greater number of organisms. Locales with greater resource variety can support species with different ecological needs (Tilman & Pacala 1993). In fact, Potts *et al.* (2004) showed that nectar diversity, which is strongly related to plant species richness, is a major factor structuring pollinator community composition. Additionally, the increase in resource quantity (i.e., number of flowering plants) may reduce competi-

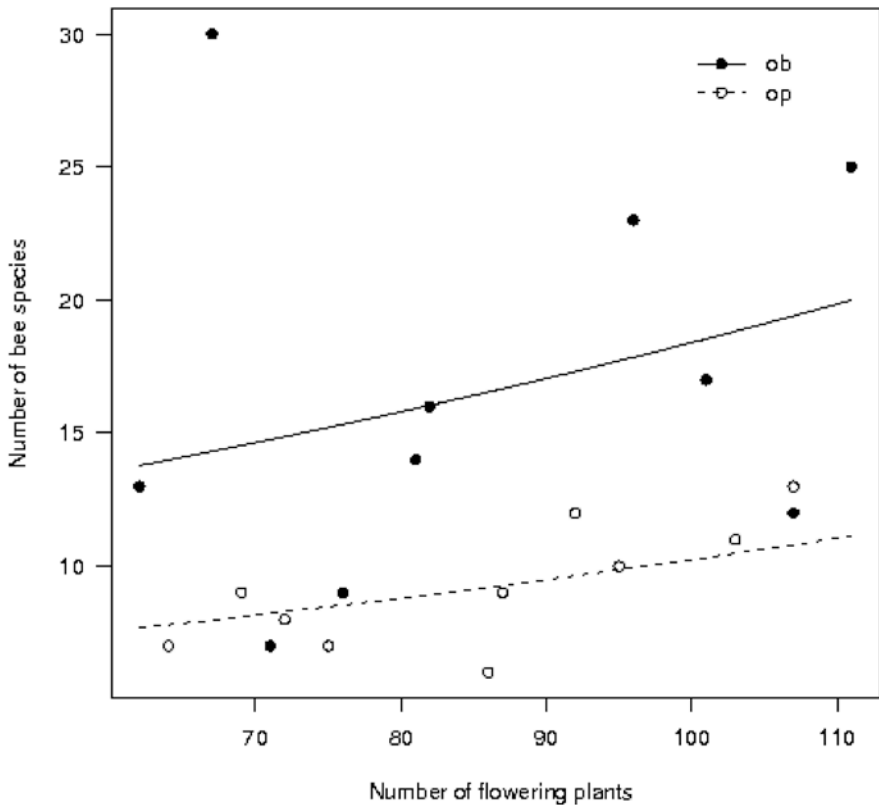


Fig. 3. Relationship between the number of flowering plants and bee species richness. Sampling site also affected species richness. OB = Ouro Branco and OP = Ouro Preto. Brazil, Minas Gerais state.

tion, promoting population increases and preventing competitive exclusion (Cornell & Lawton 1992). Beyond the effect of resources in bee communities, the increase in resource availability measured here could also correspond to an increase in nesting sites. Brosi (2009) showed that Meliponine species richness and abundance did not correlate with plant density or plant species richness, but were positively related to the proportion of forest cover. This evidenced the effect of nesting sites for some Meliponini species that prefer to nest in tree cavities (Roubik 1989).

The two sites sampled supported a relatively low number of bee species compared to other studies in Savanna areas. Araújo *et al.* (2006) surveyed the bee fauna and flora in this region for two years and attributed the low bee species richness to the strong anthropogenic impact on the regions studied

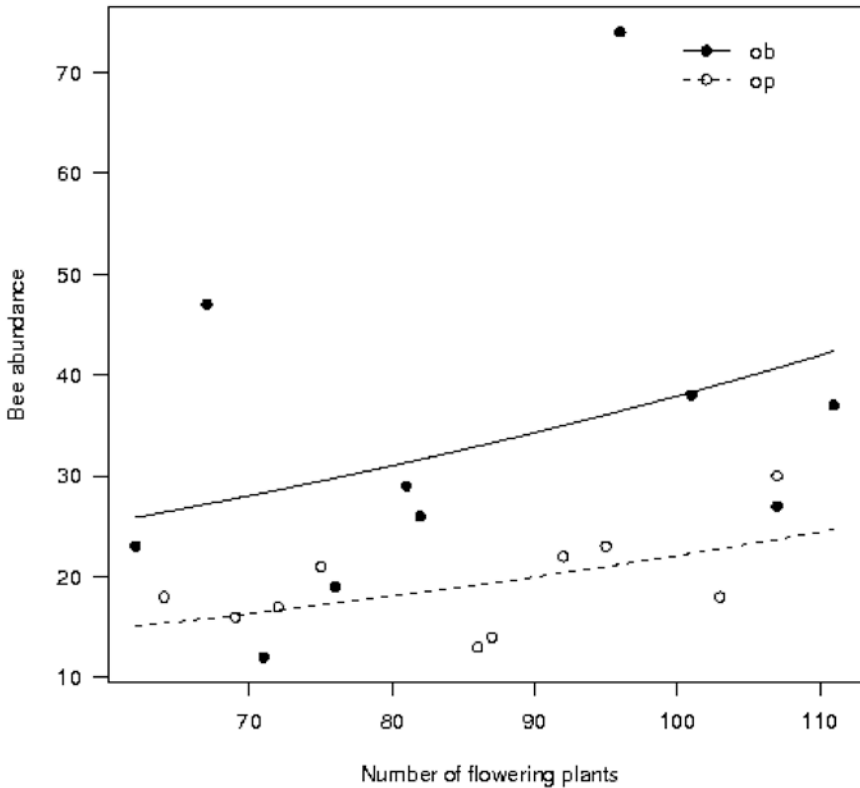


Fig. 4. Relationship between the number of flowering plants and bee abundance. Sampling site also affected species richness. OB = Ouro Branco and OP = Ouro Preto. Brazil, Minas Gerais state.

and the scarcity of tree nesting substrates. The bee diversity difference in both sites was probably due to the fact that the Ouro Preto region has suffered greater anthropogenic impact than the Ouro Branco region. However, factors acting on regional scales can also determine the local species composition through migration and extinction processes. Both habitats have differences in the local plant species composition and bee communities can establish themselves according to the flora composition (Moldenke 1975; Kevan *et al.* 1997; Minckley *et al.* 1999; Potts *et al.* 2003).

Our results corroborate others that found a negative effect of deforestation on bee communities. Brown & Albrecht (2001) found a strong relationship between the species richness of *Melipona* and forest cover. Klein *et al.* (2002) demonstrated a negative relationship between land-use intensity and the diversity and abundance of social bees. The negative effect of habitat fragmentation on bee activity has also been demonstrated for crop pollination, especially in tropical regions (Rickerts *et al.* 2008).

In conclusion, this study suggests that factors acting on a local scale, such as resource variety and amount, can determine bee abundance and richness. Thus protecting and managing natural habitat may be important to conserve bee communities.

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