REVISTA BRASILEIRA DE

Entomologia

A Journal on Insect Diversity and Evolution

www.rbentomologia.com

ELSEVIER

Biology, Ecology and Diversity

Bee assemblage in habitats associated with *Brassica napus* L.

Rosana Halinski*, Andressa Linhares Dorneles, Betina Blochtein

Laboratory of Entomology, Department of Biodiversity and Ecology, Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, RS, Brazil

A B S T R A C T

Assessments in agricultural crops indicate that alterations in the landscape adjacent to the crops can result in reduced productivity due to loss or low abundance of pollinating agents. In the canola crop, production is partially dependent on insect pollination. Therefore, knowledge of the faunal diversity within and near crop fields is key for the management of these insects and consequently for the increase in productivity. This study aimed to determine and compare the diversity of bees in habitats associated with canola fields in southern Brazil. Bees were captured in four agricultural areas using pan traps in three habitat classes: (1) flowering canola crop, (2) forest remnant, and (3) grassland vegetation. The highest abundance of bees was observed in the grassland vegetation (50%) and in the flowering canola field (47%). Eight species common to the three habitat classes were recorded, four of which are represented by native social bees. In addition, a single or a few individuals represented species that were exclusive to a specific habitat class; eight species were collected exclusively in the interior of the canola field, 51 in the grassland vegetation, and six in the forest remnant. The majority of the rare species recorded exhibits subsocial or solitary behaviour and inhabit open places. The composition of bee groups differed between the habitats showing the importance of maintaining habitat mosaics with friendly areas for pollinators, which promote the pollination service for canola flowers.

© 2015 Sociedade Brasileira de Entomologia. Published by Elsevier Editora Ltda. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Introduction

Assessments in agricultural crops indicate that alterations in the landscape of habitats adjacent to plantation fields and the consequent loss of pollinating agents result in reduced productivity (Vaissiere et al., 1996; Vicens and Bosch, 2000). Thus, the presence of pollinators of certain crops is dependent on the quality of the areas surrounding the plantation fields (Klein et al., 2003). The production of coffee plantations near forest remnants increases by approximately 15%, a result related to pollination services (De Marco and Coelho, 2004). Currently, 33% of the plants cultivated for human consumption depend on pollination, which is usually performed by bees (Klein et al., 2007). On a global scale, the pollinators contributed with 9.5% of the total production crops used for human food in 2005 (i.e., EUR 153 billion) (Gallai et al., 2009).

Brassica napus L. oleifera variety, known as canola, is the third most cultivated oleaginous plant in the world, and its seed production is partially dependent on insect pollination (Tomm et al., 2010). In 2012, the cultivated area of canola was 43,800 ha, with 41,500 ha

of this area residing in southern Brazil (Conab, 2013). The production of this crop is targeted at obtaining oil for human consumption and for biodiesel production (Marjanović-Jeromela et al., 2008).

Although canola is self-fertile, its productivity is increased by insect visitation to its flowers, with *Apis mellifera* considered the main pollinator (McGregor, 1976; Abrol, 2007; Rosa et al., 2010). This bee species has been studied extensively, but studies with native bees are scarce, despite their important role in the pollination of canola plants (Morandin and Winston, 2005). Studies have identified a number of limiting factors for producing canola seeds, including environmental conditions, compensatory ability of the crop, and the frequency of floral visitors (Mesquida et al., 1988; Free, 1993). In Canada, the introduction of three *A. mellifera* colonies per hectare promoted an increase of 46% seeds yield of canola (Sabbahi et al., 2005). In Brazil, pollination of *B. napus* (Hyola 432 cultivar) performed by free visit of insects resulted in a 22% increase in seed production compared with autogamy (Rosa et al., 2010).

Knowledge of the regional fauna of potential pollinators in agricultural areas is necessary for the establishment of strategies aimed at increasing the productivity of canola seeds. Therefore, this study aimed to determine the diversity of bees in the habitats associated with canola production in southern Brazil and to compare the bee species composition between these different habitats.

---

* Corresponding author.
E-mail: ro.halinski@gmail.com (R. Halinski).

Table 1
List of bee species collected from August 2010 to October 2011 in Esmeralda, Rio Grande do Sul, Brazil.

Taxa	Flowering canola field				Forest remnant				Grassland vegetation			
	NI	M	Do	Colour	NI	M	Do	Colour	NI	M	Do	Colour
Andreninae												
Anthrenoides ornatus (Urban, 2005)	0				0				1	11	r	Y
***Anthrenoides* sp. 1**	**1**	**8**	**r**	**W**	0				0			
Anthrenoides sp. 2	0				0				1	12	r	Y
Oxaea austera (Gerstaecker, 1867)	0				0				1	3	r	W
Psaenythia sp. 1	0				0				1	3	r	Y
Psaenythia sp. 2	0				0				1	11	r	W
Psaenythia sp. 3	0				0				1	3	r	B
Rhophitulus sp. 1	0				0				4	8, 11	r	Y, B, W
***Rhophitulus* sp. 2**	**1**	**8**	**r**	**W**	0				0			
Rhophitulus sp. 3	0				0				1	11	r	Y
Apinae												
Apis mellifera (Linnaeus, 1758)	223	8–10	E	Y, B, W	0				31	1, 4, 5, 7–11	S	Y, B, W
Bombus pauloensis (Friese, 1913)	6	8, 9	R	Y, B	2	2	r	Y, W	15	2–4, 7, 8, 12	S	Y, B, W
Ceratina rupestres (Holmberg, 1884)	0				0				9	9, 11, 12	R	Y, B
Exomalopsis trifasciata (Brèthes, 1910)	0				0				1	3	r	Y
Exomalopsis sp. 1	0				0				4	1, 3, 7, 11	r	B
Exomalopsis sp. 2	0				0				1	11	r	B
Exomalopsis sp. 3	0				1	9	r	W	0			
Melissodes nigroaenea (Smith, 1854)	0				0				2	5, 12	r	Y, B
Mourella caerulea (Friese, 1900)	20	8–10	S	Y, B, W	3	11	r	Y	5	3, 9–12	R	Y, B
Peponapis fervens (Smith, 1879)	0				0				1	2	r	B
Ptilothrix cf. *plumata* (Smith, 1853)	0				0				16	1, 3, 4, 10–12	S	Y, B, W
Scaptotrigona bipunctata (Lepeletier, 1836)	24	8–10	S	Y, B, W	1	6	r	W	31	4–9, 11	S	Y, B, W
Tapinotaspoides sp.	0				1	11	r	B	1	3	r	B
Thygater analis (Lepeletier, 1841)	0				0				1	1	r	B
Thygater mourei (Urban, 1961)	23	8–10	S	B	0				1	9	r	B
***Thygater* sp.**	**2**	**8, 9**	**r**	**B**	0				0			
Trigona spinipes (Fabricius, 1793)	7	9, 10	R	Y, B, W	1	6	r	B	8	2, 5, 6, 8, 12	R	Y, B, W
Colletinae												
Colletes sp.	0				0				1	8	r	W
Tetraglossula anthracina (Michener, 1989)	0				0				5	3	R	Y, B
Halictinae												
Augochlora amphitrite (Schrottky, 1909)	6	9, 10	R	Y, B, W	1	9	r	B	28	1, 2, 4, 6–12	S	Y, B, W
Augochlora sp. 1	0				1	2	r	W	2	8, 11	r	B, W
Augochlora sp. 2	0				0				1	1	r	Y
Augochlora sp. 3	0				0				1	6	r	W
Augochlora sp. 4	0				0				1	5	r	B
Augochlora sp. 5	0				1	12	r	B	1	2	r	B
Augochlora sp. 6	0				0				1	3	r	Y
Augochlora sp. 7	0				1	10	r	B	0			
Augochlora sp. 8	0				0				2	3, 10	r	Y, W
Augochlora sp. 9	0				0				1	7	r	B
Augochlora sp. 10	0				1	2	r	W	1	3	r	B
Augochlora sp. 11	1	10	r	W	0				3	6, 7	r	Y, W
Augochlora sp. 12	1	9	r	Y	1	9	r	W	3	1, 6, 11	r	Y, B, W
Augochlora sp. 13	0				0				2	3–4	r	W
Augochlora sp. 14	0				0				1	6	r	W
Augochlora sp. 15	0				0				1	7	r	B
Augochlora sp. 16	0				0				1	5	r	W
Augochlora sp. 17	0				0				1	8	r	Y
Augochlora sp. 18	0				0				1	1	r	B
Augochlora sp. 19	0				0				1	3	r	W
Augochlora sp. 20	0				0				1	5	r	B
Augochlora sp. 21	0				0				1	8	r	B
Augochlora sp. 22	0				0				3	1, 6, 7	r	Y, W

Table 1 (*Continued*)

Taxa	Flowering canola field				Forest remnant				Grassland vegetation			
	NI	M	Do	Colour	NI	M	Do	Colour	NI	M	Do	Colour
Augochlorella sp. 1	0				0				1	6	r	B
Augochlorella sp. 2	0				1	9	r	W	3	9	r	Y, W
Augochloropsis cf. *cupreola* (Cockerell, 1900)	1	10	r	Y	0				2	5	r	Y, W
Augochloropsis multiplex (Vachal, 1903)	0				0				1	7	r	Y
Augochloropsis sympleres (Vachal, 1903)	0				0				2	1	r	Y
Augochloropsis sp. 1	0				2	11	r	W	0			
Augochloropsis sp. 2	0				2	8, 11	r	Y, W	0			
Augochloropsis sp. 3	**2**	**9**	**r**	**B**	0				0			
Augochloropsis sp. 4	0				1	1	r	Y	0			
Augochloropsis sp. 5	0				0				1	4	r	W
Augochloropsis sp. 6	0				0				1	11	r	B
Augochloropsis sp. 7	0				1	1	r	Y	0			
Caenohalictus cf. *incertus* (Schrottky, 1902)	0				0				1	3	r	Y
Caenohalictus tesselatus (Moure, 1940)	0				0				2	12	r	B
Caenohalictus sp. 1	**1**	**10**	**r**	**B**	0				0			
Caenohalictus sp. 2	0				0				1	3	r	Y
Caenohalictus sp. 3	0				0				2	1, 12	r	Y
Caenohalictus sp. 4	**1**	**10**	**r**	**B**	0				0			
Caenohalictus sp. 5	0				0				1	12	r	B
Ceratalictus clonius (Brèthes, 1909)	0				0				1	12	r	W
Dialictus pabulator (Schrottky, 1910)	8	8–10	R	Y, B, W	1	11	r	W	13	3, 7–9, 11, 12	R	Y, B, W
Dialictus sp. 1	0				1	9	r	W	3	3, 9, 11	r	Y, W
Dialictus sp. 2	7	9, 10	R	Y, B, W	1	11	r	B	107	1–3, 5–12	E	Y, B, W
Dialictus sp. 3	5	9, 10	R	B, W	0				30	1, 3, 6–8, 11	S	Y, B, W
Dialictus sp. 4	1	10	r	B	0				5	3, 7, 9, 11, 12	R	Y, W
Dialictus sp. 5	0				0				1	11	r	Y
Dialictus sp. 6	0				0				1	11	r	Y
Paroxystoglossa cf. brachycera (Moure, 1960)	**1**	**10**	**r**	**B**	0				0			
Pseudagapostemon pruinosus (Moure and Sakagami, 1984)	9	8–10	R	Y, B, W	0				37	1–3, 5, 7, 10–12	S	Y, B
Pseudagapostemon tesselatus (Cure, 1989)	68	8–10	D	Y, B, W	0				13	1, 2, 6, 7, 9, 11, 12	R	Y, B
Pseudagapostemon sp. 1	0				0				2	2, 9	r	B
Pseudagapostemon sp. 2	0				0				1	11	r	B
Pseudagapostemon sp. 3	**1**	**10**	**r**	**B**	0				0			
Pseudagapostemon sp. 4	0				0				5	2, 6, 10, 12	R	Y, B, W
Megachilinae												
Megachile sp.	0				0				2	1, 11	r	Y

NI, number of individuals; M, number of months; Do, dominance, where E, eudominant; D, dominant; S, subdominant; R, recessive; r, rare; and pan trap colour, where Y, yellow; B, blue; W, white. Species in bold were recorded only in the interior of the flowering canola field.

Material and methods

Study area

The study was conducted in four areas near and within *B. napus* fields (Hyola 420 cultivar) in the municipality of Esmeralda, state of Rio Grande do Sul (RS), Brazil. The region is characterized by pasture land, forest fragments, and fields of annual crops (canola, soya, wheat and maize). The four plantation fields of canola studied sized 20 ha (field 1, Fig. 1), 80 ha (2), 100 ha (3), and 80 ha (4) and were far from each other 2.5 and 23.5 km. These plantation fields are located in the ecoclimatic region of the Serra do Nordeste upper plateau, with average annual temperatures of 14.4–16.8 °C, a relative humidity of 76–83%, an annual precipitation of 1412–2162 mm, and an altitude of 944 m (Veloso et al., 1992). According to the Köppen classification, the region is considered Cfa – humid temperate (Alvares et al., 2013), and the original vegetation is composed of Mixed Ombrophilous Forest and Grassland. Employment of a summer (maize and soybean) and winter (canola and wheat) crop rotation system is typical in the region.

Sampling design

On each area, the diversity of bees was evaluated in three habitat classes: flowering canola fields, forest remnant, and grassland vegetation. The sampling of bees was performed using blue, yellow, and white pan traps, which remained exposed for 24 h per sampling (adapted from Westphal et al., 2008). These traps were arranged in plots, which consist in five groups of three pots, keeping a distance of 15 m between the groups and a distance of 3 m between the pots, forming an equilateral triangle (adapted from FAO, 2010). The pan trap method is the most efficient for collecting in agricultural and seminatural habitats (Westphal et al., 2008). The sampling effort consisted of four plots per sampling per area: two in the grassland vegetation and two in the forest remnant, located near canola fields. Samples were collected monthly throughout a year in 2010 and 2011. On each area, during the canola flowering season (August–October), three plots were sampled within canola field in the distances 25, 175 and 325 m of the border of forest remnant, totalling four samplings in 2010 and seven in 2011 in each canola field. For comparison between the habitats classes,
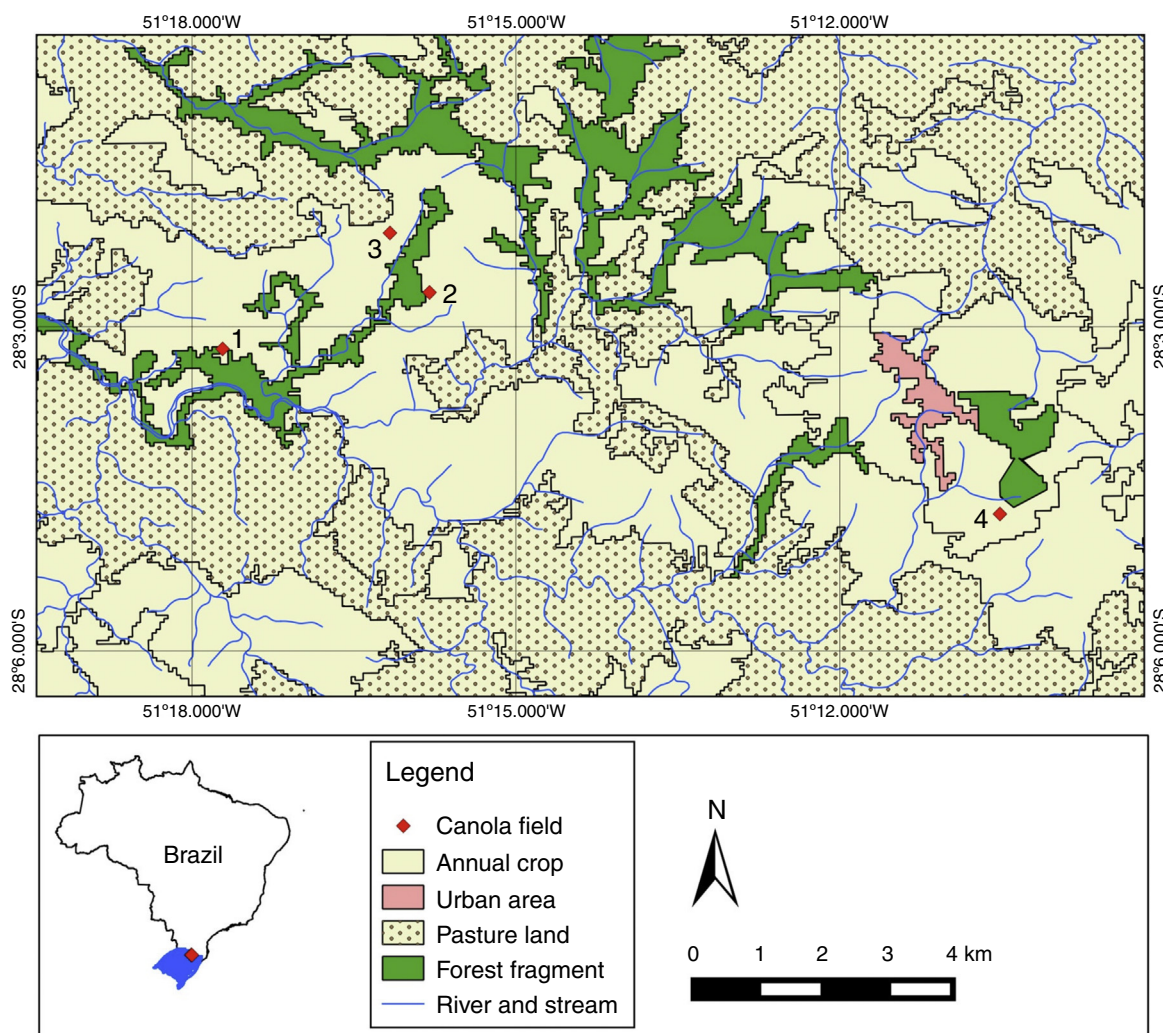
Fig. 1. Thematic map of land cover in Esmeralda, Rio Grande do Sul, Brazil.

the results will be present together, because the composition of landscape is homogeneous.

The bees were identified and deposited at the Bee Collection of the Museum of Science and Technology, Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS).

Data analysis

The software PAST was used to analyze the species abundance and richness (Hammer and Harper, 2003). The rarefaction curve was used to measure the sampling sufficiency (Krebs, 1998). The indices Sobs, Chao 1 and 2, first and second-order Jackknife, and Bootstrap were adopted to evaluate species richness. The estimators were obtained using the PRIMER 6.0 software (Clarke and Gorley, 2006).

Bees were grouped according to their degree of sociality and their original geographic distribution for comparisons between habitat classes. Three categories were thus considered: exotic social (*A. mellifera*), native social (Meliponini and Bombini), and subsocial or solitary native. The diversity indices were compared pairwise between groups of bees and between habitats using the PAST software to evaluate significant differences for these factors ($p < 0.01$) (Hammer and Harper, 2003).

Species dominance was classified according to the categories of Friebe (1983): eudominant, >10%; dominant, 5–10%; subdominant, 2–5%; recessive, 1–2%; and rare, <1%. $D\% = (i/t).100$, where i is the

total number of individuals of one species, and t is the total number of individuals collected.

Results

During the study, 886 bees belonging to 87 species were collected. Apinae was the most abundant subfamily, represented by 441 individuals, 254 of which belonged to *A. mellifera*, followed by the subfamilies Halictinae (424), Andreninae (13), Colletinae (6), and Megachilinae (2) (Table 1). The highest number of individuals was collected in the grassland vegetation (50%), followed by the interior of the flowering canola field (47%) and the forest remnant (3%). Eight species occurred exclusively in the interior of the flowering canola field, 51 were observed exclusively in the grassland vegetation, and six were observed exclusively in the forest remnant; only eight species were captured in all three habitat classes (Table 1). Most species sampled were categorized as rare in three habitats, except for *A. mellifera*, native social bees (Meliponini and Bombini), and others bees of gregarious habit (*Dialictus* spp. and *Pseudagapostemon tesselatus*) (Table 1). In the interior of the flowering canola field, the abundance of captured bees was higher in yellow traps (246), whereas species richness was higher in blue traps (19) (Table 2). Regarding the grassland vegetation, the abundance was higher in yellow traps (211), although the number of species was similar in the yellow and blue traps (Table 2). Unlike

Table 2

Bees collected with pan traps in three habitats classes of agricultural areas with *Brassica napus* (Hyola 420) from August 2010 to October 2011 in Esmeralda, Rio Grande do Sul, Brazil.

Habitat class	Colour	Number of individuals	Species
Flowering canola field	Yellow	246	12
	Blue	120	19
	White	54	13
	Total	420	24
Forest remnant	Yellow	7	5
	Blue	6	6
	White	12	11
	Total	25	20
Grassland vegetation	Yellow	211	41
	Blue	147	40
	White	83	30
	Total	441	73
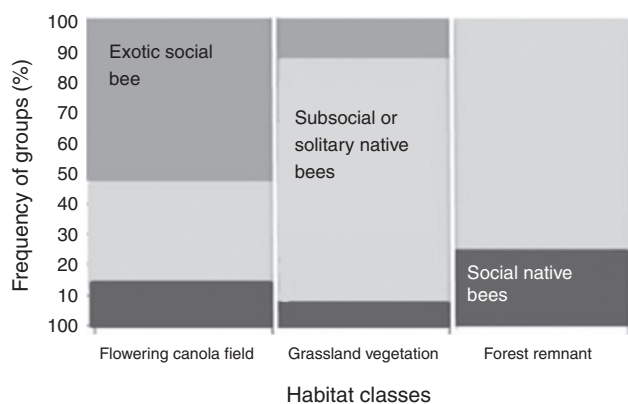
Fig. 2. Distribution of bee groups in three habitats classes of agricultural areas with *Brassica napus* (Hyola 420) from August 2010 to October 2011 in Esmeralda, Rio Grande do Sul, Brazil.

the other environments, in the forest remnant, higher abundance (12) and richness (11) were obtained in the white traps.

Regarding the frequency of bees collected, subsocial or solitary native bees predominated in the three habitat classes, although the native social bees were also observed in all of them (Fig. 2). Unlike the other groups of bees previously mentioned, exotic social bees (*A. mellifera*) were not collected in the forest remnant.

The environment with the highest abundance and species richness was the grassland vegetation, as well as the highest values for the Simpson and Pielou equitability indices. The forest remnant was the habitat class with the highest Shannon index (3.133) due to its low dominance caused by the ratio between richness and abundance (Table 3). The lowest Shannon, Simpson, and Pielou equitability indices were obtained for the flowering canola field (Table 3).

Pairwise comparison analysis of diversity indices between the three habitat classes indicated differences in the fauna found in the
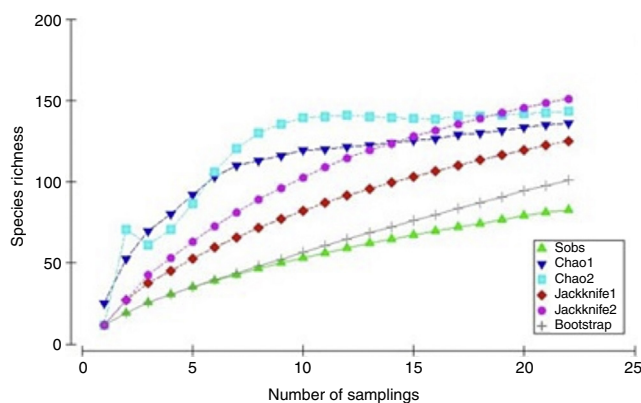
Table 3

Richness, abundance, dominance, and diversity indices of bees collected in three habitats classes of agricultural areas with *Brassica napus* from August 2010 to October 2011 in Esmeralda, Rio Grande do Sul, Brazil.

	Flowering canola field	Forest remnant	Grassland vegetation
Richness	24	20	73
Abundance	420	25	441
Dominance (%)	31.8	9.0	5.9
Shannon diversity index	1.762	3.133	2.921
Simpson diversity index	0.681	0.909	0.940
Pielou equitability index	0.554	0.730	0.974

Table 4

Pairwise comparisons of diversity indices between habitat classes and groups of bees of agricultural areas with *Brassica napus* from August 2010 to October 2011 in Esmeralda, Rio Grande do Sul, Brazil.

Factors	Significance
Habitat classes	
Flowering canola field × forest remnant	<0.001
Flowering canola field × grassland vegetation	<0.001
Forest remnant × grassland vegetation	0.996
Groups	
Exotic social bee × social native bee	<0.001
Exotic social bee × subsocial or solitary native bee	<0.001
Social native bee × subsocial or solitary native bee	0.063

Fig. 3. Estimates of bee species richness in areas with *Brassica napus* (Hyola 420) in Esmeralda, Rio Grande do Sul, Brazil.

flowering canola field compared with the forest remnant and grassland vegetation (Table 4). However, no significant difference was found between the latter two habitats. Considering the abundance of individuals in the three habitat classes, faunal diversity differed significantly with respect to the groups of bees, between the exotic social and the native social bees as well as between the exotic social and the subsocial/solitary native bees. However, the diversities of the native social bees and the subsocial/solitary native bees were similar ($p > 0.01$) (Table 4). The indices of bee richness obtained in the present study tended towards an asymptote, with the exception of the Chao 2 index, which exhibited higher stability with respect to the number of species collected (Fig. 3).

Discussion

The record of four native social bees (*Bombus pauloensis*, *Mourella caerulea*, *Scaptotrigona bipunctata*, and *Trigona spinipes*), a total of 34% of all bees collected (300 individuals), in all sampled area was presumably facilitated by the fact that these species form colonies with hundreds of individuals and exhibit a wide range of food sources (Wilms et al., 1996).

Although several bee species explore agricultural crops to collect floral resources (Holzschuh et al., 2008), this is not the only critical factor to bee survival. These insects also require breeding and nesting sites (Steffan-Dewenter and Tscharntke, 1999; Knight et al., 2009), which are usually found in natural environments (Dixon, 2009). The habitat mosaics supply these resources required by the bees to complete their life cycle (Fahrig, 2003).

The high representation of Halictinae might be attributed to the dominance of these species in open and/or secondary vegetation of southern Brazil (Bárbola and Laroca, 1993). In addition, the methodological approach with pan traps might maximize the sampling of Halictinae compared to representatives of Apinae and Megachilinae (Cane et al., 2000). *Augochlora*, *Augochloropsis*, and *Dialictus* of

the tribes Augochlorini (41 species) and Halictini (23 species) are among the genera with the highest species richness in southern Brazil (Gonçalves and Melo, 2005).

The low abundance of Colletinae and Megachilinae in the studied agricultural environments is consistent with other studies using pan traps (Cane et al., 2000; Gollan et al., 2011; Gonçalves et al., 2012), although it is possible that the number of individuals of these groups has been underestimated in this study. However, these traps are known to be effective tools for monitoring populations of anthophilous insects in fragmented environments (Aizen and Feinsinger, 1994; Leong and Thorp, 1999; Campbell and Hanula, 2007; Wilson et al., 2008; Gollan et al., 2011; Gonçalves et al., 2012).

The higher abundance and species richness in grassland could be explained by the adaptation of several bee species to open spaces (Klemm, 1996) and by the fact that these species may benefit from forest fragments, even if small ones (Tscharntke et al., 2002). In comparison to the other habitats, the high Shannon index obtained for the forest remnant is most likely due to the low abundance of bees and the correspondent high number of species. This result might be attributed to the low luminosity in the forest remnant environment and to interference in the efficacy of pan traps, whereas other methods may result in greater success for bee capture, including entomological nets and chemical baits (Michener et al., 1955; Harter, 1999; Krug and Alves-dos-Santos, 2008). However in the flowering canola field, the Shannon index was low, probably because the high abundance and dominance of *A. mellifera*. The massive presence of this species may have also directly influenced the richness of the native bees, regardless of their degree of social organization.

Comparisons of the diversity between habitat classes indicated that the canola fields significantly differed from the grassland vegetation and forest remnants with respect to diversity features. Although in the flowering canola field compared with the other environments was observed low bee richness, this result can be explained by the low activity of pollinators in the winter. No significant differences were observed with respect to species diversity between the forest remnant and the grassland vegetation; six species (30% of individuals) were collected in both habitats. In addition, the maintenance of habitat mosaics with friendly areas for pollinators seems essential for the presence of numerous species of bees. The high number of *A. mellifera* (although there is no record of apiaries in the region), a species with a wide trophic-niche and a great flight capacity (in comparison to the native bees) are factors that may explain the abundance of *A. mellifera* (Wilms et al., 1996). This species stands out as an effective pollinator of many agricultural crops, including canola (McGregor, 1976; Sabbahi et al., 2005; Abrol, 2007; Rosa et al., 2010).

The process of loss or mischaracterization of forest environments results in the reduced abundance and diversity of bees and in the modification of plant-pollinator interaction networks, thereby reducing pollination services (Winfree et al., 2009; Carvalheiro et al., 2011; Garibaldi et al., 2011). Thus, the global trend of expansion of agricultural areas to compensate for a pollination deficit (Freitas et al., 2009; Viana et al., 2012) might result in a loss of forest and grassland habitats associated with canola crops, possibly reducing the richness of bees that promote the pollination of this crop.

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgements

References

Abrol, D.P., 2007. Honeybees and rapeseed: a pollinator–plant interaction. Adv. Bot. Res. 45, 337–367.

Aizen, M.A., Feinsinger, P., 1994. Habitat fragmentation, native insect pollinators, and feral honey bees in argentine 'chaco serrano'. Ecol. Appl. 4, 378–392.

Alvares, C.A., Stape, J.L., Sentelhas, P.C., Gonçalves, J.L.M., Sparovek, G., 2013. Köppen's climate classification map for Brazil. Meteorol. Z. 22, 711–728.

Bárbola, I.F., Laroca, S., 1993. A comunidade de Apoidea (Hymenoptera) da Reserva Passa Dois (Lapa, Paraná, Brasil): I. Diversidade, abundância relativa e atividade sazonal. Acta Biol. Parana. 22, 91–113.

Campbell, J.W., Hanula, J.L., 2007. Efficiency of Malaise traps and colored pan traps for collecting flower visiting insects from three forested ecosystems. J. Insect Conserv. 11, 399–408.

Cane, J.H., Minckley, R.L., Kervin, L.J., 2000. Sampling bees (Hymenoptera: Apiformes) for pollinator community studies: pitfalls of pan-trapping. J. Kans. Entomol. Soc. 73, 225–231.

Carvalheiro, L.G., Veldtman, R., Shenkute, A.G., Tesfay, G.B., Pirk, C.W.W., Donaldson, J.S., Nicolson, S.W., 2011. Natural and within-farmland biodiversity enhances crop productivity. Ecol. Lett. 14, 251–259.

Clarke, K.R., Gorley, R.N., 2006. Primer v6: User Manual/Tutorial. PRIMER-E, Plymouth.

Conab – Companhia Nacional de Abastecimento, 2013. Brasil Grãos, Available from: http://www.conab.gov.br/ (accessed 15.07.13).

De Marco Jr., P., Coelho, F.M., 2004. Services performed by the ecosystem: forest remnants influence agricultural cultures pollination and production. Biodivers. Conserv. 13, 1245–1255.

Dixon, K.W., 2009. Pollination and restoration. Science 325, 571–573.

Fahrig, L., 2003. Effects of habitat fragmentation on biodiversity. Annu. Rev. Ecol. Evol. Syst. 34, 487–515.

FAO – Food and Agriculture Organization of the United Nations, 2010. Pollinators, Available from: http://www.fao.org/biodiversity/components/pollinators/en/ (accessed 15.07.13).

Free, J.B., 1993. Insect Pollination of Crops. Academic Press, London.

Freitas, B.M., Imperatriz-Fonseca, V.L., Medina, L.M., Kleinert, A.D.M.P., Galetto, L., Nates-Parra, G., Quezada-Euán, J.J.G., 2009. Diversity, threats and conservation of native bees in the Neotropics. Apidologie 40, 332–346.

Friebe, B., 1983. Zur Biologie eines Buchenwaldbodens. 3. Die Kaferfauna. Beitrage zur naturkundlichen Forschung in Sudwestdeutschland. Beihefte. Beitrage Naturkd Forsch Sudwestdtsch Beiheft 41, 45–80.

Gallai, N., Salles, J.-M., Settele, J., Vaissière, B.E., 2009. Economic evaluation of the vulnerability of world agriculture confronted with pollinator decline. Ecol. Econ. 68, 810–821.

Garibaldi, L.A., Steffan-Dewenter, I., Kremen, C., Morales, J.M., Bommarco, R., Cunningham, S.A., Carvalheiro, L.G., Chacoff, N.P., Dudenhöffer, J.H., Greenleaf, S.S., Holzschuh, A., Isaacs, R., Krewenka, K., Mandelik, Y., Mayfield, M.M., Morandin, L.A., Potts, S.G., Ricketts, T.H., Szentgyörgyi, H., Viana, B.F., Westphal, C., Winfree, R., Klein, A.M., 2011. Stability of pollination services decreases with isolation from natural areas despite honey bee visits. Ecol. Lett. 14, 1062–1072.

Gollan, J.R., Ashcroft, M.B., Batley, M., 2011. Comparison on yellow and white pan traps in surveys of bee fauna in New South Wales, Australia (Hymenoptera: Apoidea: Anthophila). Aust. J. Entomol. 50, 174–178.

Gonçalves, R.B., Melo, G.A.R., 2005. A comunidade de abelhas (Hymenoptera, Apidae s. l.) em uma área restrita de campo natural no Parque Estadual de Vila Velha, Paraná: diversidade, fenologia e fontes florais de alimento. Rev. Bras. Entomol. 49, 557–571.

Gonçalves, R.B., Santos, E.F., Scott-Santos, C.F., 2012. Bees (Hymenoptera: Apoidea: Apidae s. l.) captured with Malaise and pan traps along an altitudinal gradient in the Parque Estadual da Serra do Mar, Ubatuba, São Paulo, Brazil. Check List 8, 53–56.

Hammer, Ø., Harper, D., 2003. Paleontological Data Analysis. Blackwell Publishing Ltd.

Harter, B., (Dissertation) 1999. Bienen und ihre Trachtpflanzen im Araukarien-Hochland von Rio Grande do Sul, mit Fallstudien zur Bestäubung von Pionierpflanzen. Universität Tübingen.

Holzschuh, A., Steffan-Dewenter, I., Tscharntke, T., 2008. Agricultural landscapes with organic crops support higher pollinator diversity. Oikos 117, 354–361.

Klein, A.M., Steffan-Dewenter, I., Tscharntke, T., 2003. Fruit set of highland coffee increases with the diversity of pollinating bees. Proc. R. Soc. B 270, 955–961.

Klein, A.M., Vaissiere, B.E., Cane, J.H., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C., 2007. Importance of pollinators in changing landscapes for world crops. Proc. R. Soc. B 274, 303–313.

Klemm, M., 1996. Man-made bee habitats in the anthropogenous landscape of central Europe-substitutes for threatened or destroyed riverine habitats? In: Matheson, A., Buchmann, S.L., O'Toole, C., Westrich, P., Williams, I.H. (Eds.), The

Conservation of Bees. Linnean Society Symposium Series, vol. 18. Academic Press Ltd., pp. 17–34.

Knight, M.E., Osborne, J.L., Sanderson, R.A., Hale, R.J., Martin, A.P., Goulson, D., 2009. Bumblebee nest density and the scale of available forage in arable landscapes. Insect Conserv. Divers. 2, 116–124.

Krebs, C.J., 1998. Ecological Methodology, second ed. Longman, New York.

Krug, C., Alves-dos-Santos, I., 2008. The use of different methods to sample the bee fauna (Hymenoptera: Apoidea), a study in the mixed temperate rainforest in Santa Catarina State. Neotrop. Entomol. 37, 265–278.

Leong, J.M., Thorp, R.W., 1999. Colour-coded sampling: the pan trap colour references of oligolectic and nonoligolectic bees associated with a vernal pool plant. Ecol. Entomol. 24, 329–335.

Marjanović-Jeromela, A., Marinković, R., Mijić, A., Zdunić, Z., Ivanovska, S., Jankulovska, M., 2008. Correlation and path analysis of quantitative traits in winter rapeseed (Brassica napus L.). Agric. Conspec. Sci. 73, 13–18.

McGregor, S.E., 1976. Insect Pollination of Cultivated Crop Plants. United States Department of Agriculture, Washington, DC.

Mesquida, J., Renard, M., Pierre, J.-S., 1988. Rapeseed (Brassica napus L.) productivity: the effect of honeybees (Apis mellifera L.) and different pollination conditions in cage and field tests. Apidologie 19, 51–72.

Michener, C.D., Cross, E.A., Daly, H.V., Rettenmeyer, C.W., Wille, A., 1955. Additional techniques for studying the behavior of wild bees. Insectes Soc. 2, 237–246.

Morandin, L.A., Winston, M.L., 2005. Wild bee abundance and seed production in conventional organic, and genetically modified canola. Ecol. Appl. 15, 871–881.

Rosa, A.S., Blochtein, B., Ferreira, N.R., Witter, S., 2010. Apis mellifera (Hymenoptera: Apidae) as a potencial Brassica napus pollinator (cv. Hyola 432) (Brassicaceae), in Southern Brazil. Braz. J. Biol. 70, 1075–1081.

Sabbahi, R., de Oliveira, D., Marceau, J., 2005. Influence of honey bee (Hymenoptera: Apidae) density on the production of canola (Crucifera: Brassicacae). J. Econ. Entomol. 98, 367–372.

Steffan-Dewenter, I., Tscharntke, T., 1999. Effects of habitat isolation on pollinator communities and seed set. Oecologia 121, 432–440.

Tomm, G.O., Ferreira, P.E.P., Aguiar, J.L.P., Castro, A.M.G., Lima, S.M.V., Mori, C., 2010. Panorama atual e indicações para aumento de eficiência da produção de canola no Brasil. Embrapa Trigo, Passo Fundo (Embrapa Trigo. Documentos Online, 118).

Tscharntke, T., Steffan-Dewenter, I., Kruess, A., Thies, C., 2002. Contribution of small habitat fragments to conservation of insect communities of grassland-cropland landscapes. Ecol. Appl. 12, 354–363.

Vaissiere, B., Rodet, G., Cousin, M., Botella, L., Grossa, J.-P.T., 1996. Pollination effectiveness of honey bee (Hymenoptera: Apidae) in a kiwifruit orchard. J. Econ. Entomol. 89, 453–461.

Veloso, H.P., Oliveira-Filho, L.D., Vaz, A.M.S.F., Lima, M.P.M., Marquete, R., Brazao, J.E.M., 1992. Manual técnico da vegetação brasileira. IBGE, Rio de Janeiro.

Viana, B.F., Boscolo, D., Neto, E.M., Lopes, L.E., Lopes, A.V., Ferreira, P.A., Pigozzo, C.M., Primo, L.M., 2012. How well do we understand landscape effects on pollinators and pollination services? J. Pollinat. Ecol. 7, 31–41.

Vicens, N., Bosch, J., 2000. Pollinating efficacy of Osmia cornuta and Apis mellifera (Hymenoptera: Megachilidae, Apidae) on red delicious apple. Environ. Entomol. 29, 235–240.

Westphal, C., Bommarco, R., Carré, G., Lamborn, E., Morison, N., Petanidou, T., Potts, S.G., Roberts, S.P.M., Szentgyôrgyi, H., Tscheulin, T., Vaissière, B.E., Woyciechowski, M., Biesmeijer, J.C., Kunin, W.E., Settele, J., Stefan-Dewenter, I., 2008. Measuring bee diversity in different European habitats and biogeographical regions. Ecol. Monogr. 78, 653–671.

Wilms, W., Imperatriz-Fonseca, V.L., Engels, W., 1996. Resource partitioning between highly eusocial bees and possible impact of the introduced Africanized honey bee on native stingless bees in the Brazilian Atlantic Rainforest. Stud. Neotrop. Fauna Environ. 31, 137–151.

Wilson, J.S., Griswold, T., Messinger, O.J., 2008. Sampling bee communities (Hymenoptera: Apiformes) in a desert landscape: are pan traps sufficient? J. Kans. Entomol. Soc. 81, 288–300.

Winfree, R., Aguilar, R., Vázquez, D.P., LeBuhn, G., Aizen, M.A., 2009. A meta-analysis of bees' responses to anthropogenic disturbance. Ecology 90, 2068–2076.