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RESEARCH ARTICLE

Preliminary results of bowl trapping bees (Hymenoptera, Apoidea) in a southern Brazil forest fragment

Rodrigo B. Gonçalves[1] Priscila S. Oliveira[1]

[1]*Laboratório de Hymenoptera, Universidade Federal do Paraná – Palotina, Av. Pioneiro 2153, CEP 85950-000, Palotina, Paraná, BRAZIL. E-mail: goncalvesrb@gmail.com*

Abstract: In recent years bowl traps have gained attention as a useful method for sampling bees and are now commonly used across the world for this purpose. However, specific questions about the method itself have not yet been tested on different regions of the globe. We present the preliminary results of bowl trapping in a Semidecidual Seasonal forest fragment in southern Brazil, including the test of two different color bowls, two different habitats, and the interaction of these variables in bee species number and composition. We used blue and yellow bowls in the border and in the core trails of the forest fragment. In five sampling days between October to December bowl traps captured 745 specimens of 37 morphospecies, with Halictinae bees being the richest and most abundant group. Non parametrical statistical analyses suggested that different colors of bowl traps influenced bee richness and composition and thus, they should be used together for a more complete sampling. Different trails influenced only the composition, while the interaction with different colors did not have a significant effect. These results, as well as the higher taxonomic composition of the inventoried bees, are similar to other studies reported in the literature.

Key words: Pan traps, assemblage, synecology, bees, Apoidea

Introduction

Bees are considered a target group for survey and study since they are essential contributors, bioindicators and/or keystones organisms, in natural and agricultural ecosystems

(Kevan 1999; Raven & Wilson 1992). Structured inventories or systematic surveys provide data to understand the role of bees in ecosystems which is useful for detecting long-term faunal alterations, such as those caused by global warming (Gonçalves *et al.* 2012; Williams *et al.* 2001). In these inventories, bees are commonly sampled by hand-netting, and melittologists, especially Brazilians, have adopted the standard protocol of collecting bees at flowers, in a delimited area or transect, for a year period (Sakagami *et al.* 1967). Alternative methods for sampling bees such as malaise, scent baits, nests, and bowl traps, are frequently viewed as less efficient methods when compared with hand-netting, especially in terms of richness and composition of assemblages (Cane *et al.* 2001; Laroca & Orth 2002).

The use of bowl traps (also known as pan traps or Moericke traps) is based on the assumption that color is one of the main flowering plants attractants for bees (Kevan 1972; Leong & Thorp 1999). This method has recently gained increased attention among melittologists, especially after the contribution of Droege *et al.* (2010). Published studies from Brazil reached to different conclusions about the performance of this sampling method, some reporting efficient captures (Krug & Alves-Dos-Santos 2008; Souza & Campos 2008), but others reporting very poor performances (Gonçalves & Brandão 2008; Gonçalves *et al.* 2012). Currently, at least 11 studies using pan traps have been carried out in different regions of the country (as reported by Simões *et al.* 2012).

As summarized by Grundel *et al.* (2011), bowl traps and hand-netting are complementary useful tools in a structured inventory, each one with its particularities. Bowl traps are considered better standard procedure for sampling effort, because there is not collector biases and easily replicated for sampling multiple transects simultaneously (Krug & Alves-dos-Santos 2008; Droege *et al.* 2010). Another important issue when designing sampling is the low cost-benefit of bowl traps (Westphal *et al.* 2008): commercial plastic bowls are cheap and only water and soap are added. Wilson *et al.* (2008) reported the superiority of bowl trapping when few flowers are available in a transect, thus bowls could be a promising application on forested and fragmented areas where collecting flower visiting bees is difficult.

It is important to highlight the disadvantages of bowl trapping when compared with hand-netting. According to Cane *et al.* (2001), bowl traps have selective biases, especially for the collection of many large-bodied species (Roulston *et al.* 2007; Minckley 2008; but see Krewenka *et al.* 2001; Stephen & Rao 2005 reports of bumblebee sampling). Also, they have a low performance when compared with hand-netting and malaise traps in dense forested areas (Gonçalves & Brandão 2008; Gonçalves *et al.* 2012). Other important issues are related to the type and placement of bowl traps, which can influence their efficiency (Gollan *et al.* 2010), such as spacing among each unit (Droege *et al.* 2010), elevation of the traps (Campbell & Hanula 2007; Tuell & Isaacs 2011), bowl colors and selectivity of bees (Campbell & Hanula 2007; Krug & Alves-dos-Santos 2008; Wilson *et al.* 2008), habitat heterogeneity (Droege *et al.* 2010), and fragment size (Aizen & Feinsinger 1994).

Our objective is to provide the preliminary results of a bowl trapping initiative in a Semideciduous Seasonal forest of southern Brazil (Paraná State), designed to investigate the preference of bees, number and composition of species, on the color of the bowl trap used (blue and yellow), the effect of transect heterogeneity (border vs. inside the forest). Our results can assist in the experimental design of further studies in the area.

Material and Methods

Sampling was conducted in the Parque Estadual de São Camilo (PESC), located at Palotina municipality, western Paraná state in Brazil (geographic UTM coordinates -24.312998, -53.917491). PESC is a 385 ha conservation unit, with a humid subtropical climate, hot summers, and located under a Submontane Semideciduous Seasonal forest, Atlantic Forest biome (IAP 2006). The area is surrounded by alternate soybean and corn crops, being one of the few forest fragments under conservation on western Paraná.

We used commercial plastic bowl traps, blue and yellow, with 14.5 cm of diameter at upper surface, 10 of diameter on mid portion, and six of height, filled one third of its volume with a water/soap solution. Traps were placed in two habitats: the first transect was between the border of PESC and the surrounding crop; the second transect was a trail inside the forest about 2 m wide. At each transect 24 bowl traps of each color were placed on the ground, alternated and spaced 10 m apart from each other. Both habitats were sampled at the same time; the location of each bowl trap on each trail was randomly selected. A total of five sampling days were carried in spring 2011 (October to December) the season of the first activities of bees, in the beginning of the wet season and when the trees were full of leaves. Samplings were carried out at intervals from two to three weeks. Bees were pinned, identified to morphospecies, databased, and deposited at Laboratório de Hymenoptera, Setor Palotina, Universidade Federal do Paraná (PAUP). Species determination was done at the Departamento de Zoologia, Universidade Federal do Paraná (DZUP). We follow the bee higher classification of Melo & Gonçalves (2005), in which the families in traditional classifications are simply treated as subfamilies, so all bees are considered under Apidae.

For data analysis, we first applied Levene`s test for homogeneity of variances, and as samples were heterogeneous, we opted for a non-parametric analysis. To test the effects of color and transect on richness, we performed a Friedman test, treating each trap as a replicate, and a chi-square test for a contingency table of pooled pan trap color and transect by sampling day. For composition analysis we firstly carried out a non-parametric multivariate variance analysis (NP-MANOVA) for samples using Bray-Curtis similarity index, which was also calculated for grouped samples by sampling day. A cluster analysis was also performed over this later for the cophenetic correlation. All analyses were performed with Past (Hammer *et al.* 2001).

Results

Bowl traps sampled 745 specimens, representing 37 species and morphospecies, and 16 genera (Table 1). Among bee higher taxonomical groups, Halicinae were the most common with 23 species and 719 specimens, followed by Apinae with 11 species and 14 specimens, and Andreninae with three species and 13 specimens. The prevalence of Halictinae is supported by the richness of *Dialictus* and *Augochlora*, with 12 species and seven species respectively. *Augochlorella ephyra* (Schrottky, 1910) had an extremely high abundance, with more than one half of bees collected (496 specimens), contrasting to the almost one half of species (18) sampled only as singletons.

Table 1. Bees sampled in the Parque Estadual de São Camilo by transect location and bowl color (see text for explanation).

	Border transect		Trail transect		
Species	yellow bowl	blue bowl	yellow bowl	blue bowl	Total
ANDRENINAE					
Anthrenoides cyphomandrae Urban, 2005			1		1
Anthrenoides meridionalis (Schrottky, 1906)	2	1	2		5
Oxaea flavescens Klug, 1807	2	5			7
APINAE					
Ceratina sp-1	1				1
Ceratina sp-2		1			1
Diadasina distincta (Holmberg, 1903)	1				1
Eulaema nigrita (Lepeletier, 1841)	1				1
Exomalopsis analis Spinola, 1853	3				3
Exomalopsis auropilosa Spinola, 1853		1			1
Melitoma nudipes (Burmeister, 1876)	1				1
Peponapis fervens (Smith, 1879)		1			1
Plebeia droryana (Friese, 1900)			1		1
Tetrapedia diversipes Klug, 1810	1		1		2
Trichocerapis cfr. *mirabilis* (Smith, 1865)				1	1
HALICTINAE					
Augochlora amphitrite (Schrottky, 1909)	1	4			5
Augochlora thalia Smith, 1879	13	25			38
Augochlora sp-1	7	11		2	20
Augochlora sp-2	2	7	2	3	14
Augochlora sp-3				1	1
Augochlora sp-4			1		1
Augochlora sp-5			1		1
Augocholorella ephyra (Schrottky, 1910)	72	246	56	122	496
Augochlorella tredecim (Vachal, 1911)		1			1
Augochloropsis sp-1	1	2		1	4
Augochloropsis sp-2				1	1
Dialictus sp-1			5		5
Dialictus sp-2		1			1
Dialictus sp-3		1			1
Dialictus sp-4	1	1			2
Dialictus sp-5		1	1		2
Dialictus sp-6	2	4			6
Dialictus sp-7	3	5	1	3	12
Dialictus sp-8		1	1		2

Dialictus sp-9		3	4	1	8
Dialictus sp-10	18	26	38	10	92
Dialictus sp-11	2	2			4
Neocorynura crf. *pseudobaccha* (Cockerell, 1901)				1	1

Pooling data from all five sampling days, most individuals were collected in blue bowls at the border transect (Table 2). The Friedman test suggested significant differences for both color and transect variables (df: 2, *p*: <0001) indicating an influence of both on the species richness (Table 3). The chi-square test for the contingency table with samples grouped by day indicated no association among variables (df:12, Chi square:8.54, *p*:0,74) suggesting that different colors and habitats do not influence bee richness of the samples taken together. For composition analysis, NP-MANOVA suggested significant differences for color (df:1, F:5.1, *p*:0.003) and transect (df:1, F: 10.47, *p*:0.0001), but not for interaction among these variables (df:1, F:2.91, *p*:0.011) (Table 4). Similarity indexes for all five sampling days presented elevated correlation cophenetic values (above 0.83 for all the cases), and composition varied among sampling days according to the different colors and habitat transects. Blue pan traps produced more similar assemblages in two sampling days, yellow pan traps in one sampling day, the trail transect was accounted for one, and in one sampling day both blue and yellow bowls showed more similar fauna.

Table 2. Number of species and individuals by transect location and bowl color.

		Species	Individuals
Border transect	Yellow bowl	19	134
	Blue bowl	22	350
Trail transect	Yellow bowl	14	115
	Blue bowl	11	146

Table 3. Friedman test for bees sampled in Parque Estadual de São Camilo by transect location and bowl color.

	Color	Transect	Species number
Color	0	0,44	<0.001
Transect	1	0	<0.001
Species number	2,26E-007	3,59E-007	0

Table 4. NP Manova for bees sampled in Parque Estadual de São Camilo by transect location and bowl color.

	df	F	p
Color	1	5,1	<0.001
Transect	1	10,47	<0.001
Interaction	1	2,91	0,01
Residual	476	0,32	

Discussion

We found an abundance of species and individuals of sweat bees as in other pan trap studies (Campbell & Hanula 2007; Droege *et al.* 2010; Gollan *et al.* 2010, Roulston *et al.* 2007; Tuell & Isaacs 2011). Halictinae is one of commonest group of bees, overcoming other bees in many areas (Michener 2007), and this accumulate knowledge indicates that the group is easily attracted and sampled by pan traps than other groups. Aizen & Feinsinger (1994) showed a greater richness of Apinae for Argentinean Chaco, but *Augochlora* and *Dialictus* morphospecies were not sorted in their study. For Brazil, such abundance of Halictinae has been previously recorded, including the higher richness of *Dialictus* (Krug & Alves-dos-Santos 2008; Souza & Campos 2008) confirming the prevalence of the group. *Dialictus* is a group also strongly sampled by netting in southern Brazil, as reported by Krug & Alves-dos-Santos (2008), Gonçalves *et al.* (2009), Sakagami *et al.* (1967). It is possible that *Dialictus* is the most species-rich genus in many localities, and as mentioned by Krug & Alves-dos-Santos (2008), bowl traps can sample different species from those collected by netting.

The presence of representatives of Andreninae and Apinae and the absence of Colletinae and Megachilinae (groups previously known for the study site by the authors) were also a pattern recovered in other Brazilian localities using bowl traps (Krug & Alves-dos-Santos 2008; Souza & Campos 2008), but see Aisen & Feinsinger (1994) and Droege *et al.* (2010) for studies where these groups were sampled.. The introduced honey bee (*Apis mellifera* Linnaeus, 1758), a species attracted to bowls (Krug & Alves-dos-Santos 2008; Droege *et al.* 2010), were not sampled in this study, but its presence in the study area was confirmed by personal observation and hand-netting.

The blue/yellow capture ratio varies according to different studies, A higher number of captures of blue bowl traps, measured by richness and abundance, has been observed in other studies, such as those of Campbell & Hanula (2007), Grundel *et al.* (2011), while Krug & Alves-dos-Santos (2008) found yellow bowl traps as more efficient, and Wilson *et al.* (2008) found almost the same species numbers from yellow and blue traps. In PESC, blue bowl traps sampled more bees at the border transect, but in the trail transect yellow traps performed better. According to our results, color may have an influence on richness among samples in a period of sampling, but not when grouping the samples, and may have a slight influence on composition; therefore, it seems appropriate to use of both colors to have a more complete sampling. Different colors can also be employed to deal with the differential preferences of certain bee groups for a particular color (Campbell & Hanula 2007). White bowl traps, which usually have the worst performance (Krug & Alves-dos-Santos 2008, see also Gollan *et al.* 2010), were not evaluated, but should be considered for inventory purposes.

Studies about the effect of different transects on bowl trap sampling are scarce. Droege *et al.* (2010), compiling several initiatives in North America, suggested a dispersed distribution of bowl traps throughout a study site to deal with the clumped distribution of bees according to habitat preferences. Abrahamczyk *et al.* (2010), studying Hymenoptera as a whole, suggested that forest cover influences the proportion of capture by different bowl trap colors because of the visibility conditions. Our results suggest little influence of habitats on the bee species number and composition, but we consider the importance of different habitats for a complete inventory of species composition. A good dispersion of pan traps throughout the study area will increase the probability that bees restricted to one part of the study area will be sampled, either because more bowl traps would mean more chance for a bee to be caught as well as increase the overall visibility of bowls amid vegetation. On the other hand, when sampling several areas at the same time, restricting the number of habitats to maintain a comparable and cost-effective sampling effort may be a better strategy, as for fragmentation studies (see Aizen & Feinsinger 1994).

Our results indicate that bowl traps performances, and the higher taxonomic composition of the captures as influenced by bowl colors and transects on bee richness and composition, are quite similar to other published studies, and document and encourage the growing application of these traps in Brazil, irrespective of the criticisms about efficacy of bowl trapping relative to netting.

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Correspondance: Rodrigo B. Gonçalves, e-mail: *goncalvesrb@gmail.com*
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