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Species of *Drosophila* (Diptera: Drosophilidae) attracted to dung and carrion baited pitfall traps in the Uruguayan Eastern Serranías

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ABSTRACT. This study investigates the species richness and abundance of *Drosophila* Fallén, 1823 attracted to dung and carrion baited pitfall traps in natural areas with heterogeneous habitats at the Sierra de Minas, Eastern Serranías, southeastern Uruguay. Collecting was carried out on a monthly basis (May 2002 through April 2003). Drosophilids accounted for 0.84% (n = 131) and 3.61% (n = 158) of the Diptera collected from dung (n = 15,630) and carrion (n = 4,382) pitfall traps, respectively. A total of 12 species were identified, 11 of which belong to the subgenus *Drosophila* (the richest) and one to the subgenus *Sophophora* Sturtevant, 1939. Over 90% of the *Drosophila* specimens collected belong to five species of the subgenus *Drosophila*, namely *D. gaucha* Jaeger & Salzano, 1953, *D. immigrans* Sturtevant, 1921, *D. mediovittata* Frota-Pessoa, 1954, *D.* aff. *nappae* Vilela, Valente & Basso-da-Silva, 2004, and *D. ornatifrons* Duda, 1927. *Drosophila cardini* Sturtevant, 1916 is recorded for the first time from Uruguay. *Drosophila* abundance and species richness in the four habitats sampled in the Uruguayan Eastern Serranías, namely woodlands sierra, riparian forest, pine plantation and grazing grassland, were considered to be a function of habitat conservation. Diversity indices were low in all habitats. Different habitats supported particular coprophilous and necrophilous *Drosophila* species. The woodland sierra represents the most preserved habitat, and contributed with the highest species richness observed. *Drosophila ornatifrons* was the dominant species, with a restricted habitat distribution. On the other hand, grazed grassland, an environment modified by livestock management, had the lowest species richness: only a few specimens of *D. repleta* Wollaston, 1858. Regarding species composition, significant differences were found in some pairwise comparisons of groups of *Drosophila* species that included *D. ornatifrons*. Fly attraction to dung can be exploited as an alternative and/or complementary collecting method in ecological studies of *Drosophila* assemblages in natural areas.

KEY WORDS. Biodiversity; coprophilous; Drosophilinae; necrophilous; Neotropical Region.

Conventional dung and carrion traps, known as baited pitfall traps, have been occasionally used to collect insects, especially beetles, for ecological studies. In general, Hymenoptera and Diptera are attracted to these traps. Ecological studies on the necrophilous entomofauna in tropical and subtropical forests and plantations in the Mexican transition zone by Morón & Terrón (1982, 1984), Morón & López-Mendéz (1985), Morón *et al.* (1986) and Deloya *et al.* (1987) showed that Diptera and Hymenoptera (Formicidae), together with Coleoptera, are the dominant insect orders, both in diversity and abundance, and that they are sensitive to habitat disturbances. Low representation of drosophilids was observed among Diptera samples in Otongo and Tlanchinol (Hidalgo, Mexico) during 1981 (Morón & Terrón 1984): specimens were recorded in areas of very disturbed tropical forest, 2.80% (n = 727 in 25,995 collected Diptera) and 0.66% (n = 94 in 14,185) at 650 and 1,120 m altitude respectively, and at a slightly disturbed area of a montane forest at 1,550 m altitude, 1.57% (n = 39 in 2,481). Morón & López-Mendéz (1985) reported that Drosophilidae were the second most abundant flies, 38.31% (n = 1,706 in 4,453 adult Diptera), after Phoridae (46.58%, n = 2,074), amongst the necrophilous entomofauna collected in a coffee-cacao plantation, located at 430 m altitude on the slopes of Tacaná volcano, finca San José de La Victoria, Chiápas, Mexico. Drosophilids were also sampled [1.57% (n = 23 in 1,461 Diptera)] at the tropical rain forest of the Northern area of the “Sian Ka’an” Biosphere Reserve, Quintana Roo, Mexico, located at 10 m altitude, during 1984-1985 (Morón *et al.* 1986). Additional reports have indicated that Drosophilidae were identified among necrophilous insects sampled from the Mexican regions of Jojutla (Deloya *et al.* 1987) and Tamaulipas (Sánchez-Ramos *et al.* 1993). In these studies, squid or marine fish meat were used as baits in pitfall traps. Those were replaced biweekly or monthly and 95 parts of ethanol 70° and 5 parts of glacial acetic acid (Morón & Terrón 1984) or commercial antifreeze liquid (Sánchez-Ramos *et al.* 1993) were used as preservative solutions. As stated by Morón & Terrón (1984), the preservative solutions they used do not mask the fetid volatile odors from bait, but instead enhance the attractiveness of the bait to other saprophagous insects (as Drosophilidae).

At southern latitudes, Remedios *et al.* (2012) reported flies of Drosophilidae among Diptera sampled in pitfall traps in natural areas at the Sierras de Minas, Department of Lavalleja, Uruguay.

Since the samples in the research papers cited above have not been identified to species, the efficacy of pitfall traps as an alternative collecting method for Drosophilidae diversity and ecological studies remains to be assayed.

Mid-latitude South American lowlands gain particular importance when the ecological patterns for faunal groups are examined. Besides some ecological and distributional considerations on *Drosophila* species, mostly from collecting at south and southeast Uruguay, reported by Goñi *et al.* (1997, 1998), drosophilid diversity in the natural areas locally known as sierras or cuchillas is almost unknown. The most extensive sierras in Uruguay, known as the Serranías del Este (Eastern Serranías), cover a half moon – shaped area at southeastern Uruguay (Fig. 1, forward-slashed area at right). They have a rugged topography, with altitudes ranging from 200 to 500 m, where the key element is the unevenness between peaks and foothills, and the steep slopes. The geological basement of the Eastern Serranías System is varied and complex, especially in the southern area. Different geological formations (interspersed granitoid and last postectonic granitoids, basaltic lavas, limestone, and Pliocenic sandstones and Pleistocenic loess) are found within very short distances. This geological diversity is reflected into a variety of soil types (from the dominant shallow soils to moderately and very deep ones) associated with rocky and stony outcrops. The average annual temperature is 17°C, with an annual rainfall between 1,000 mm and 1,200 mm (Evia & Gudynas 2000). The typical sierra landscape consists of fault ridges with a regular range of hills and streams interspersed between them, and covered predominantly by patches of woody and shrubby vegetation and rocky outcrops. The Sierra de las Animas is located at the southernmost point of the Eastern Serranías, and the Sierra de Minas to the west, whereas nearby the Serranías de Sauce, Cabral and Caracoles are formed. These sierras present a major south-north axis, separated by valleys of several streams. This region is ecologically very significant, because of the wide extent of natural areas that harbor a rich fauna and flora, and has suffered little human impact. Moreover, soils of the sierras are in general suitable for forestry-related activities, in particular pine and eucalyptus plantations, which have been implemented in the last 20 years in areas traditionally occupied by grasslands (Evia & Gudynas 2000). Considering the mosaic distribution of the typical diverse natural ecosystems of the sierras, such as woodlands and shrub lands, grasslands, rocky and riparian forests, and the rich fauna and flora, the sierras are of great interest to researchers and conservationists (Evia & Gudynas 2000, Brazeiro *et al.* 2008).

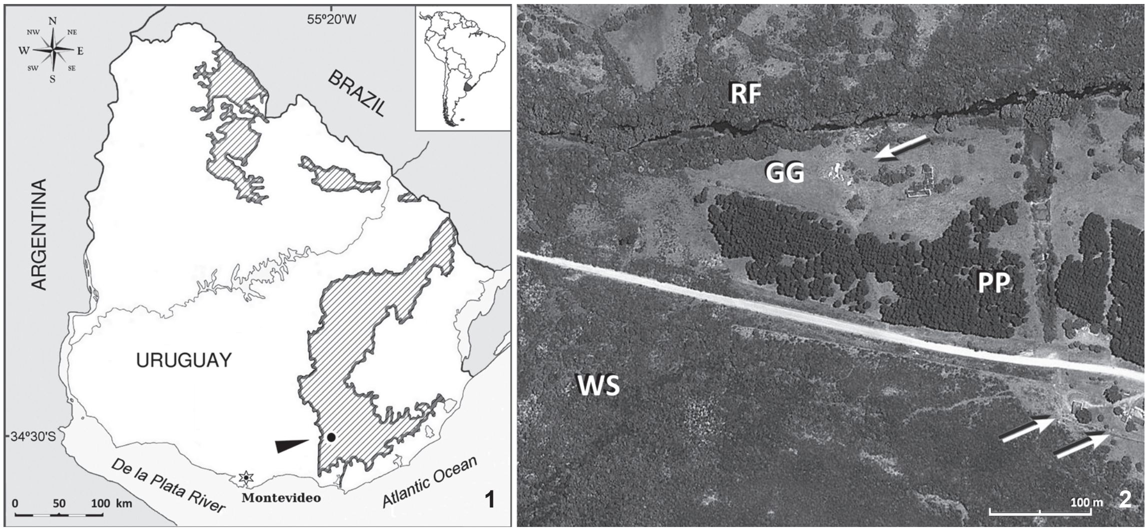
The purpose of the present study was to investigate the abundance and species composition of *Drosophila* attracted to dung and carrion baited pitfall traps placed in natural areas of Sierra de Minas, with different grades of anthropogenic disturbance, and compare the spatial distribution of the species and their association with habitat disturbance, as part of a research project on ecological studies on Uruguayan dung and carrion beetles (González-Vainer & Morelli 2008).

MATERIAL AND METHODS

Collecting was carried out monthly within an area of 10 km^2 at the Sierra de Minas, Department of Lavalleja, Uruguay, from May 2002 through April 2003. The area is adjacent to Route 81, km 105-112 at the south of the Eastern Serranías system, between 34°30'59"S, 55°20'07"W and 34°30'54"S, 55°19'53"W (Fig. 1). This area includes Cerro Mirador at 370 m altitude and other unnamed lower elevations, whose eastern side gently slopes down to the Mataojo creek. It is characterized by silt loam uliginous soil, with altitude varying from 110 to 230 m (González-Vainer & Morelli 2008). Four areas, representing different habitats, were selected for sampling (Fig. 2):

Woodlands sierra (WS). It is a natural area formed by woody and shrubby vegetation on the slopes of the hills. It has a dense vegetation of xerophytic stunted and gnarled shrubs and trees, ca 1-3 m tall, with closed canopy, ferns, and associated epiphytes. Plant species include *Aloysia gratissima* (Gillies & Hook. ex Hook.) Tronc. (Verbenaceae), *Azara uruguayensis* (Speg.) Sleumer (Salicaceae), *Colletia paradoxa* (Spreng.) Escal. (Rhamnaceae), *Dodonaea viscosa* Jacq. (Sapindaceae), *Berberis laurina* Billb. (Berberidaceae), *Lithraea brasiliensis* Marchand (Anacardiaceae), *Myrcianthes cisplatensis* (Cambess.) O. Berg (Myrtaceae), *Scutia buxifolia* Reissek (Rhamnaceae), *Celtis spinosa* Spreng. (Cannabaceae), *Iodina rhombifolia* Hooker & Arnot. (Santalaceae), *Blepharocalyx salicifolius* (Kunth) O. Berg (Myrtaceae), *Myrsine laetevirens* (Mez) Arechav. (Myrsinaceae), and *Myrrhinium atropurpureum* Schott (Myrtaceae) (Muñoz *et al.* 1993).

Riparian forest (RF). It is a natural area characterized by a 5 to 7 m tall dense vegetation fringe formed by shrubs and trees along the Mataojo creek. Plant species include *Pouteria salicifolia* (Spreng.) Radlk. (Sapotaceae), *Salix humboldtiana* Willd. (Salicaceae), *Cephalanthus glabratus* (Spreng.) K. Schum. (Rubiaceae), species of intermediate height such as



Figures 1-2. (1) Location of the study area in the Uruguayan Eastern Serranías (arrowhead). Northern and Eastern Serranías unit (forward slashes), modified from Evia & Gudynas (2000). (2) Satellite photograph (from *Google Earth* free virtual globe, map and geographical information program) showing part of the sampled area where coprophilous and necrophilous insects were collected. Woodlands sierra (WS), riparian forest (RF), grazing grassland (GG), and pine plantation (PP). Arrows indicate rural houses.

Sebastiania commersoniana (Baill.) L. B. Sm. & Downs (Euphorbiaceae), *Eugenia uniflora* L. (Myrtaceae), and xerophilous species in the periphery such as *Rapanea laetevirens* Mez (Myrsinaceae), *Celtis spinosa* Spreng. (Cannabaceae), *Schinus longifolius* (Lindl.) Speg. (Anacardiaceae), and *Scutia buxifolia* Reissek (Rhamnaceae) (Muñoz *et al.* 1993).

Pine plantation (PP). It is an artificial *Pinus elliottii* Englem. (Pinaceae) plantation, established in 1987 on previously natural grassland covering 1.5 ha, and is used as a refuge by cattle. It is adjacent to the grazing grassland area and is located 1-2 km away from the sierras natural areas.

Grazing grassland (GG). Narrow corridors (1.5 ha) of grasslands between the riparian forest and the pine plantation areas, managed year round to provide food for livestock. Herbs and grass species forming pastures include *Axonopus* P. Beauv. spp. (Panicoideae), *Paspalum notatum* Flüggé (Panicoideae), *P. dilatatum* Poir., *P. plicatulum* Michx., *Vulpia australis* (Steud.) Blom (Pooideae), and *Stipa charruana* Arechav. (Pooideae) (Millot *et al.* 1987).

Two independent replicates of each habitat, located 1 km apart, were surveyed monthly from May 2002 through April 2003. Coprophilous and necrophilous insects were sampled using pitfall traps baited with cow dung (from livestock fed local grasses) or cow liver, buried with the rim at ground level and filled with an aqueous solution of formaldehyde (10%) and a drop of detergent (Figs 3-5). The bait (150 g) was placed in the middle of the upper plastic jar, which was perforated in its bottom, allowing insects to fall into a second jar containing the preserving fluid (Fig. 3). In each habitat, three pitfall traps were placed at 20 m intervals, resulting in a total of 288 traps. Baited traps remained in place for a week; the captured insects were sorted in the laboratory. All dipteran insects were preserved in ethanol 70% until identification. *Drosophila* samples were counted and identified to species using characters of the external morphology and, in some cases, the male and/or female terminalia, according to the method detailed by Bächli *et al.* (2004). The keys and/or illustrations of Freire-Maia & Pavan (1949), Frota-Pessoa (1954), Brncic & Santibañez (1957), Spassky (1957), Val (1982), Vilela (1983), Vilela & Bächli (1990), Bächli *et al.* (2000), and Vilela *et al.* (2004) were used. Male and female specimens used for species identification were double-mounted (glued to cardboard tips soon after drying, according to Bächli *et al.* 2004: 3), labeled and deposited as vouchers at the Museu de Zoologia, Universidade de São Paulo (Brazil), and at the collection of Sección Entomología, Departamento de Biología Animal of the Facultad de Ciencias, Universidad de la República, Montevideo (Uruguay).

Total sample estimates of species richness and abundance in each habitat were used to compute the following ecological indexes: Shannon ($H' = -\Sigma$ pi ln pi), Berger-Parker ($d = Nmax/N$) and Pielou evenness ($E = H'/Hmax$) (Magurran 1988). Paired-sample Student's t tests (Zar 1994) were used to examine differences in species diversity between dung and carrion baited pitfall traps. A matrix was constructed using absolute abundance of samples in each habitat and each species at dung and carrion baited traps. Sample-based rarefaction curves were constructed to assess species richness for each habitat according to baited trap. The resultant curve is a plot of the number of species as a function of the number of samples, which also minimizes the effect of the absence of samples by loss of traps. Rank abun-

Figures 3-5. Schematic representation of the dung (or carrion) baited pitfall trap (3) used in this study containing the bait (above) and the fixative (below). The pitfall trap (4) before being buried with the rim at ground level (5).

dance analyses (Whittaker plots) were built to display the relative species abundance attracted to both dung and carrion baited trap in each habitat. The rank abundance curve provides a means for visually representing species richness and species evenness. Analysis of similarities (ANOSIM, CLARKE 1993) was performed to statistically test whether the species attracted to dung or carrion baited traps varied significantly between habitats. Analysis of Similarity Percentage (SIMPER, CLARKE 1993) was used to assess the contribution of each species to the average Bray-Curtis dissimilarity between habitats. The relationships between habitats or species composition in dung or carrion baited traps were analyzed using Morisita similarity index (KREBS 1999), followed by cluster analysis using the UPGMA method (SNEATH & SOKAL 1973). For statistical analysis (natural logarithmic transformation in number of individuals) ln (n + 1) was used. All data analyses were carried out using PAST version 2.09 (HAMMER *et al.* 2001) and Biodiversity Pro version 2.0 (Biodiversity Pro: Free Statistics Software for Ecology).

RESULTS

In this study over 20,000 Diptera were collected at the Sierra de Minas in a twelve-month period (Tab. I). Most of them were coprophagous (78.10%, n = 15,630) with a lower percentage of necrophagous (21.90%, n = 4,382). Temporal and spatial variations in abundance were observed among dung and carrion traps samples. Diptera were most abundant from October to December, then again in March and April, most probably due to the total precipitation peaks recorded in those (or immediately previous) months (Fig. 6). Considering the accidental loss of some monthly samples, the spatial and temporal data on Diptera composition in each habitat should be viewed as tentative.

A total of 289 drosophilids (131 in dung traps and 158 in carrion traps), belonging to 12 species of *Drosophila*, were identified: eleven species in the subgenus *Drosophila* and one species (*D. willistoni* Sturtevant, 1916) in the subgenus *Sophophora* (Tab. II). With the exception of *Drosophila cardini* Sturtevant, 1916 and two undescribed species of the *tripunctata* group, the remaining nine species had been previously recorded from Uruguay (GOÑI *et al.* 1997, 1998).

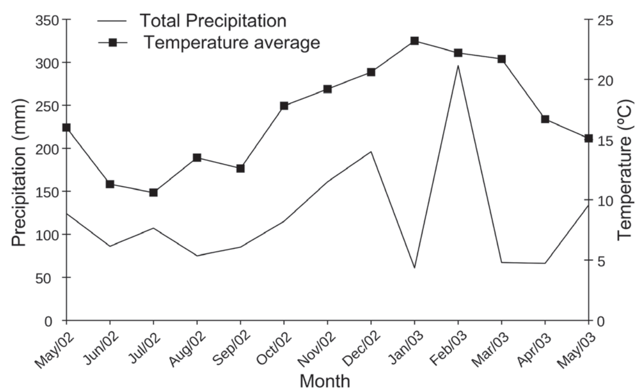


Figure 6. Temperature and rainfall monthly averages during the study period. Source: Dirección Nacional de Meteorología, Uruguay.

The rarefaction curves of *Drosophila* species attracted to dung and carrion traps have shown that more (unrecorded) species may occur in the study area (Figs 7-8). *Drosophila* richness at the woodlands sierra (WS) habitat is likely to yield nearly 14 species, whereas the steep slope of species richness observed in the other three habitats indicates that additional species are expected to occur.

The diversity indices were low in all habitats (Tab. II). Non-significant differences were found at the 5% level (Student's t test) regarding species diversity in relation to the bait, dung *vs* carrion, in three out of the four analyzed habitats, WS (t = 1.17, v = 229.1, p = 0.24), RP (t = -1.47, v = 2.8, p = 0.24), and PP (t = -0.02, v = 8.9, p = 0.99). The abundance of species attracted to dung and carrion baited traps in each habitat are shown in Figu-

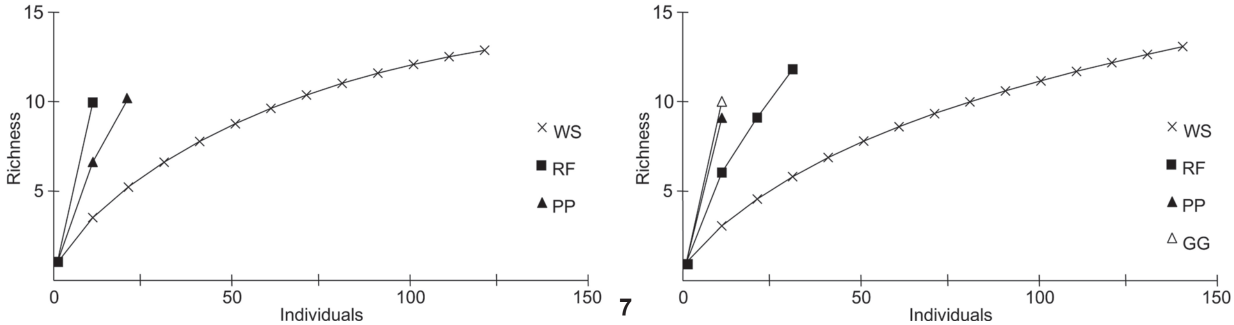
Table I. Abundance of Diptera collected in four habitats at the Sierra de Minas, Department of Lavalleja, Uruguay, from May 2002 to April 2003.

Habitat/Baited pitfall traps	2002								2003				Total
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
Woodlands sierra/Dung	0	30	0	0	0	558	516	102	94	115	145	439	1999
Carrion	0	22	0	0	0	250	92	35	24	16	33	686	1158
Riparian forest/Dung	0	0	0	0	0	775	457	965	47	0	36	170	2450
Carrion	0	0	0	0	0	1984	294	65	31	14	64	361	2813
Pine plantation/Dung	0	0	0	0	0	473	732	6170	23	201	549	113	8261
Carrion	0	0	0	0	0	5	46	11	14	0	28	120	224
Grazing grassland/Dung	0	0	0	0	0	156	568	1992	54	0	90	60	2920
Carrion	0	0	0	0	0	14	34	30	13	2	45	49	187
Total	0	52	0	0	0	4215	2739	9370	300	348	990	1998	20012

Table II. Species richness, abundance of *Drosophila* spp. and ecological indexes calculated for each habitat surveyed at the Sierra de Minas, Department of Lavalleja, Uruguay, from May 2002 to April 2003. Dung (D) and carrion (C) baited pitfall traps.

Species group	Species	Woodlands sierra				Riparian forest				Pine plantation				Grazing grassland		Total
		Dung		Carrion		Dung		Carrion		Dung		Carrion		Carrion		
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	
cardini	*D. cardini*	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2
guarani	*D. ornatifrons*	33	58	29	82	0	0	0	0	0	0	0	0	0	0	202
immigrans	*D. immigrans*	0	1	0	6	0	0	2	11	1	0	0	0	0	0	21
mesophragmatica	*D. gaucha*	0	0	1	1	0	0	1	5	2	7	0	1	0	0	18
repleta	*D. hydei*	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
	D. mercatorum	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
	D. meridionalis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	D. repleta	0	0	0	0	0	1	0	0	0	0	0	0	1	1	3
tripunctata	*D. mediovittata*	0	1	0	5	0	1	0	1	0	2	0	1	0	0	11
	D. aff. *nappae*	8	1	1	1	0	0	2	1	2	3	1	1	0	0	21
	D. aff. *paraguayensis*	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2
willistoni	*D. willistoni*	1	3	1	0	0	0	0	0	0	0	0	1	0	0	6
Total		45	67	32	96	0	2	5	18	5	12	1	4	1	1	289
Abundance		112		128		2		23		17		5		2		
Richness		9		7		2		4		4		4		1		
Diversity (Shannon-Wiener, H')		0.80		0.60		0.69		1.08		1.12		1.33		0.00		
Dominance (Berger-Parker, d)		0.81		0.87		0.50		0.57		0.53		0.40		1.00		
Evenness (Shannon, E)		0.37		0.81		1.00		0.78		0.80		0.96		0.00		

res 9-11. The GG habitat was excluded from this figure because only a few samples were collected in it, all of which from carrion baited traps (Tab. II). The WS habitat contributed between 75% and 58% of the observed species richness registered in dung and carrion baited traps, respectively (Tab. II). By contrast, there is a sharp fall in the species abundance curves for the RP and PP habitats. These habitats, surrounded by open fields, contributed with relatively moderate species richness, between 17% to 33% in RP (dung and carrion baited traps, respectively), and 33% in PP habitats (Tab. II). One species, *D. ornatifrons* Duda, 1927, was the most abundant species in WS habitat and accounted for 83% and almost 87% of the individuals attracted to dung and carrion baited traps, respectively (Figs 9-11). This endemic species was restricted to the WS habitat. Other species, *D. gaucha* Jaeger



Figures 7-8. Rarefaction curves of species richness estimates of *Drosophila* recorded for each habitat, in (7) dung and (8) carrion baited traps. Woodlands sierra (WS), riparian forest (RF), pine plantation (PP), and grazing grassland (GG).

& Salzano, 1953, *D. immigrans* Sturtevant, 1921, *D.* aff. *nappae* Vilela, Valente & Basso-da-Silva, 2004 have a slighter wider distribution in all habitats surveyed at the Sierra de Minas, except the GG habitat (Figs 9-11). The GG habitat, modified by livestock management, showed the lowest species richness and absolute abundance, with only one species, *D. repleta* Wollaston, 1858, recorded in carrion baited traps.

Different habitats supported particular coprophilous and necrophilous *Drosophila* species as shown by the ANOSIM analyses (Global R = 0.09, p = 0.008 for the dung baited trap group, and R = 0.04, p = 0.04 for the carrion-baited trap group, respectively). As expected, significant differences in species composition were found within some pairwise comparisons of *Drosophila* species (Tab. III). The SIMPER analysis pointed to *D. ornatifrons* as the taxon primarily responsible for the observed differences between some groups of samples. In dung baited traps, this species contributed with 35.01% and 33.74% of the observed differences between WS and RF, and between WS and PP habitats, respectively (the overall dissimilarity was 65.07% and 64.36%, respectively). In carrion baited traps, *D. ornatifrons* contributed with 30.11% between WS and RF habitats (showing an overall dissimilarity of 54%).

Table III. ANOSIM. Pairwise comparison of *Drosophila* species abundance and composition between habitats for dung (D) and carrion (C) baited pitfall traps.

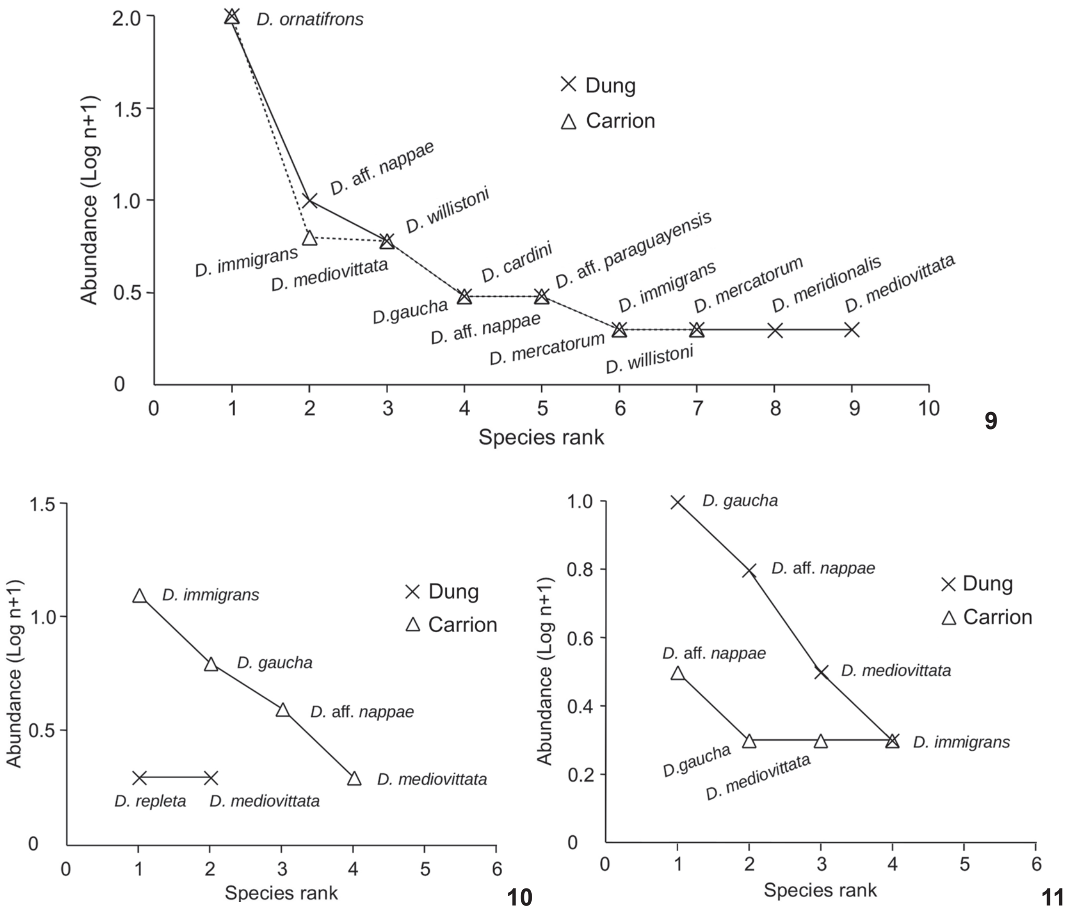
Groups	Dung		Carrion	
	R statistics	p (%)	R statistics	p (%)
WS vs. RF	0.170	1.12*	0.040	18.36
WS vs. PP	0.161	1.24*	0.070	8.54
WS vs. GG	–	–	0.134	1.56*
RF vs. PP	-0.020	100.00	-0.011	56.01
RF vs. GG	–	–	0.030	9.42
PP vs. GG	–	–	0.002	58.09

WS = Woodlands sierra, RF = Riparian forest, PP = Pine plantation, and GG = Grazing grassland. *p < 5%.

Cluster analysis using habitats association (Figs 12 and 13) showed that WS, RF and PP were associated in dung and carrion traps, with low and medium similarity values, respectively. In carrion traps (Fig. 13), GG habitat was unassociated, probably due to the low abundance and species richness, with no samples in dung traps (Tab. II). Different associations of species were obtained in dung and carrion traps (Figs 14 and 15). In dung traps (Fig. 14), two clusters of species showed the highest level of association: one formed by six species (*D. cardini*, *D. hydei*, *D. ornatifrons*, *D. meridionalis* Wasserman, 1962, *D.* aff. *paraguayensis* Duda, 1927, and *D. willistoni*) and the other by two members (*D. immigrans* and *D.* aff. *nappae*). They were associated to other *Drosophila* species at varying levels of similarity (values above 0.4). In carrion traps (Fig. 15), seven out of eight species were associated to each other at varying levels of similarity. In both types of traps, *D. repleta* was unassociated and divergent from the other species.

DISCUSSION

Drosophila ornatifrons had been previously registered in a sample collection at Cerro del Toro (34°51'15"S; 55°15'23"W), an isolated topographic accident of Sierra de las Animas, located at the southernmost region in the Eastern Serranías System, using conventional banana-baited traps (Goñi *et al.* 1998). *Drosophila ornatifrons* (also cited under its junior synonym, *D. guarani* Dobzhansky & Pavan, 1943) was formerly believed to be endemic to the Atlantic Forest biome of Brazil (Sene *et al.* 1980). However, later on, it was collected in gallery forests, xerophitic enclaves, highland rocky fields and other transitional areas between the Atlantic Forest and adjacent biomes (Araújo & Valente 1981, Tidon-Sklorz *et al.* 1994, Vilela & Mori 1997, Mateus *et al.* 2006, Tidon 2006). It was also recorded from Colombia, Bolivia and Ecuador (Rafael & Vela 2000). Temporal and spatial studies of drosophilids in the cerrado biome indicate that *D. ornatifrons* has been more frequently found in gallery forests than in the savanna-like vegetation (or cerrado), and has low but significant positive correlation with monthly humidity and light in



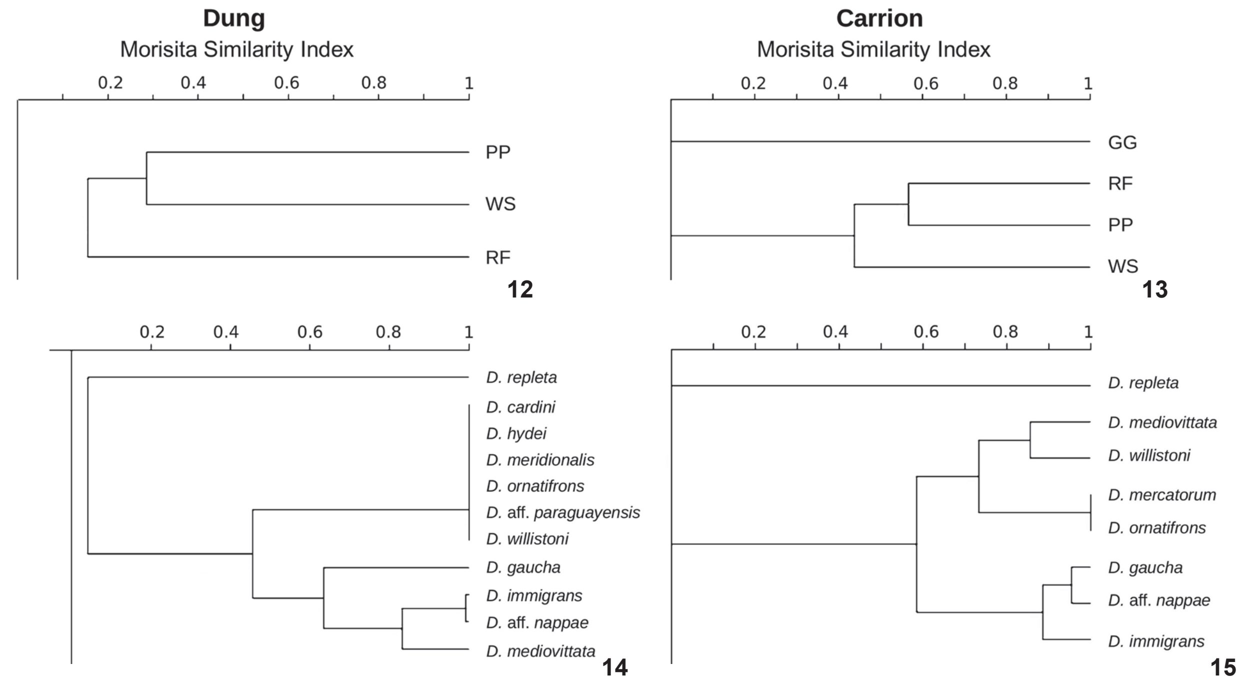
Figures 9-11. Rank–abundance curves of *Drosophila* species attracted to dung or carrion baited traps in each habitat sampled, woodlands sierra (9), riparian forest (10), and pine plantation (11). Grazing grasslands were intentionally omitted.

one of the two sites surveyed, close to the city of Brasília (Tidon 2006). Fly collecting in the Paranã Valley, located in the cerrado biome, revealed that the few collected samples of *D. ornatifrons* were associated with the wet season (Mata *et al.* 2008). There are few records on the breeding sites of this species. Araújo & Valente (1981) mentioned fallen fruits of seven species belonging to different plant families, *Schefflera morototoni* (Aublet) Maguire *et al.* (Araliaceae), *Bromelia balansae* Mez (Bromeliaceae), *Euphorbia phosphorea* Mart. (Euphorbiaceae), *Strychnus brasiliensis* (Spreng.) Mart. (Loganiaceae), *Inga* sp. (Mimosaceae), *Prunus subcoriacea* (Chodat & Hassl.) Koehne (Rosaceae), and *Randia armata* (Sw.) (Rubiaceae) in Parque do Turvo (RS, Brazil), whereas Roque *et al.* (2009) registered only one specimen of *D. ornatifrons* among 4,163 drosophilids emerged from fallen fruits of *Emmotum nitens* (Benth.) Miers (Icacinaceae) in the Brazilian savanna.

Two species of the *tripunctata* species group, *D. mediovittata* and *D.* aff. *nappae*, were not very abundant among the *Drosophila* samples collected both in dung and carrion traps. *Drosophila mediovittata* belongs to the subgroup IV (Frota-Pessoa 1954) and seems to be endemic to Brazil and Uruguay. In Uruguay, this species breeds on a limited number of substrates such as flowers of *Erythrina crista-galli* L. (Fabaceae) and on rotting cladodes of *Opuntia arechavaletai* Speg. (Cactaceae) collected from the Atlantic wetlands in the Department of Rocha (Goñi *et al.* 1998).

Drosophila immigrans is a cosmopolitan species that had been previously collected in several localities in Uruguay (Goñi *et al.* 1997, 1998).

Drosophila gaucha is the only member of the *mesophragmatica* species group that seems to be widely distributed outside the Andean region. It is found in Ecuador, Bolivia, Argentina, Brazil, and Uruguay (Jaeger & Salzano 1953, Brncic & Santibañez 1957, Brncic *et al.* 1971, Goñi *et al.* 1997, Rafael & Vela 2000). According to Brncic & Santibañez (1957) there are no morphological differences between *D. gaucha* and its sibling species, *D. pavani* Brncic, 1957. Since the latter species has never been collected in the southernmost Brazilian state of Rio Grande do Sul, which includes the type locality of the former and extends contiguously to Uruguay, the specimens collected



Figures 12-15. UPGMA dendrograms with Morisita's similarity index representing habitat (upper, 12 and 13) and *Drosophila* species association (lower, 14 and 15) attracted to dung and carrion baited pitfall traps.

were tentatively identified as belonging to *D. gaucha*.

Three species of the *repleta* species group, *D. hydei* Sturtevant, 1921, *D. mercatorum* Patterson & Wheeler, 1942, and *D. repleta* were identified in our samples. *Drosophila hydei* and *D. repleta* are cosmopolitan species, whereas *D. mercatorum* is semi-cosmopolitan. In previous collections by Goñi *et al.* (1997, 1998), *D. hydei* was frequently found associated with pristine as well as man-modified environments. In the present study, only one female specimen of *D. hydei* was sampled at the WS habitat (Tab. II). *Drosophila repleta* is a domestic species, often found in restaurants, urinals and inside houses, especially kitchens (Sturtevant 1918, Coe 1943), as well as in poultry manure, from which Bicho *et al.* (2004) identified 9,229 adults of this species among 28,720 Diptera collected, representing 32% of the flies. As just one female imago of *D. repleta* was collected in dung baited traps placed at the RF habitat, it seems that this species is not as attracted to cow dung baits, containing only feces, as it is to the semisolid mixture of feces and of uric acid of the poultry manure. Whether the uric acid is responsible for the strong attraction that poultry manure and restaurant's urinals exert on flies (Coe 1943) remains an open question. Although *D. repleta* was absent from necrophagous insect communities sampled during the decomposition of medium-sized domestic pig carcasses at a central European urban habitat (Grassberger & Frank 2004), in the present survey one male and one female of this species were collected in carrion baited pitfall traps in the GG habitat (Tab. II). The occurrence of *D. repleta* in the latter traps may indicate the presence of human settlements near the sampled areas (Fig. 2). Just one female of *D. mercatorum*, probably belonging to *D. mercatorum pararepleta*, was collected in the present study, in a carrion baited trap set at the WS habitat (Tab. II).

Finally, a few specimens of *D. cardini* were collected in dung traps at the most preserved habitat, the WS. This species has been found in Florida (USA), Mexico, Central and South America, and the West Indies, and later recorded from the Hawaiian Islands (Herforth *et al.* 1984), where it became one member of the established immigrant drosophilid species (Leblanc *et al.* 2009). In Brazil, this species has been collected in semi-arid areas such as caatingas, but can also be found in cerrados (savannas), the coast and the restingas (sand dune vegetation) (Vilela *et al.* 2002).

This is the first inventory of *Drosophila* species in Sierra de Minas using pitfall traps placed across heterogeneous natural areas within a relatively small geographic area (altitude of sampled sites varied between 110-230 m, and the longest distance between these sites was about 5 km). Endemic and cosmopolitan species were collected in almost all habitats. Among the endemic species, one previously unrecorded species from Uruguay, *D. cardini*, and two undescribed ones of the *tripunctata* group were registered. However, some widespread cosmopolitan generalists, such as *D. simulans* Sturtevant, 1919, which is frequently collected in natural areas of Uruguay (Goñi *et al.* 1998), was absent from our traps. This observation indicates that the use of pitfall traps to collect *Drosophila* might result in an underestimation of the true species richness. This hypothesis is consistent with the (higher) expected richness estimated in this study for the sampled area. The abundance and richness of endemic species (*D. cardini*, *D. ornatifrons*, *D. meridionalis*, *D.* aff. *nappae*, *D.* aff. *paraguayensis* and *D. willistoni*) are associated with habitat differences. We infer this based on the fact that statistical differences, as well as low habitat association (estimated in dung and carrion baited traps), were observed among the *Drosophila* assemblages of the sampled areas. At the most preserved area, the WS habitat, most of the species are at least partially (or totally) dependent on the forest environment, where the greatest number of species were sampled by both dung and carrion baited traps. Furthermore, in this habitat, *D. ornatifrons* was dominant with a restricted distribution, suggesting its association with local resource(s) availability and/or particular forest environmental conditions. On the other hand, in the natural modified habitat where anthropogenic disturbance was present, the abundance and richness of *Drosophila* shifted to low indices, as observed in the GG habitat, with only one species, *D. repleta*, recorded in carrion baited traps.

The results presented here indicate that carrion and dung baited pitfall traps, though not efficient in terms of expected richness, it can be exploited as an additional and reliable sampling method. However, it does not replace the more conventional traps (based only on banana or bakers' yeast-fermented banana bait) used to study *Drosophila* biodiversity and ecology. Comparative studies involving insect collections using different baits (fruits, carrion, and dung), conducted simultaneously, can be employed to test the usefulness of alternative baits for understanding more fully the dynamics of frequency and abundance of drosophilid species in natural environments. Our findings support the view that the *Drosophila* assemblage attracted to carrion and dung baited pitfall traps is quite sensitive to natural forest or natural grasslands, and can be used to monitor environmental disturbance in conservation programs along with other necrophilous and coprophilous insects.

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