

Seasonal variations of Diptera assemblages in urban green patches of Córdoba city, Argentina: same richness, different composition

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Variaciones estacionales de los ensambles de Diptera en espacios verdes urbanos de la ciudad de Córdoba, Argentina: misma riqueza, distinta composición

RESUMEN. La estacionalidad puede tener una influencia directa en la estructuración de las comunidades de insectos debido a las distintas preferencias o tolerancias a las condiciones climáticas de las especies que las componen. El objetivo de este estudio fue evaluar los cambios estacionales en dípteros adultos en espacios verdes urbanos. Los dípteros fueron colectados sobre la vegetación con una G-VAC (aspiradora) en espacios verdes urbanos de la ciudad de Córdoba, Argentina, durante el verano e invierno de 2014. Globalmente, la abundancia de dípteros fue mayor en verano que en invierno, mientras que la riqueza fue similar en ambas estaciones. Sin embargo, la riqueza por sitio fue significativamente menor en invierno, reflejando una distribución más heterogénea y un alto recambio de familias en esta estación. La composición de familias y/o sus abundancias relativas difirieron entre estaciones, reflejando la preferencia estacional de varias familias de Diptera en esta región templada del hemisferio sur.

PALABRAS CLAVE. Diversidad. Estacionalidad. Insecta. Paisaje urbano.

ABSTRACT. Seasonality can have a direct influence on the structuring of insect communities due to different preferences or tolerances to the climatic conditions of the species that compose them. The aim of this study was to evaluate seasonal changes in adult Diptera assemblages of urban green patches in a southern temperate region. Dipterans were sampled from vegetation with a G-VAC (aspirator) in urban green patches in Córdoba city, Argentina, during the summer and winter of 2014. Overall, dipterans were more abundant in summer than in winter but globally, their richness was similar. However, richness *per site* was significantly lower in the winter, reflecting a heterogeneous distribution and higher family turnover during this season. Family composition and/or their relative abundances differed between seasons, reflecting the seasonal segregation of several Diptera families in this temperate region of the southern hemisphere.

KEYWORDS. Diversity. Insecta. Seasonality. Urban landscape.

INTRODUCTION

Both arthropod abundance and species richness depend on temporal components (Schwartz, 2013), particularly seasonality, in such a way that the diversity of a given taxon can vary considerably from one season to the next, often with the peak of diversity occurring when the conditions are optimal for their development (Chatelain et al., 2018). Seasonal variations, common in nature, can impose stressful conditions on organisms and limit population growth, especially on insect communities (Wolda, 1988). Thus, fluctuations of temperature and water availability can impose physiological restrictions (Bowler & Terblanche, 2008) and modify the availability of resources necessary for the development and reproduction of individuals (Wolda, 1988).

In general, Diptera are benefited by the high temperature and precipitation of summer (Carles-Tolrá, 1997; Souza & Linhares, 1997; Alto & Juliano, 2001; Vezzani et al., 2004), but some species can be more abundant under winter conditions (Beckett, 1992; Souza & Linhares, 1997; Battán Horenstein & Gleiser, 2018). Seasonal rainfall can have effects on abundance and species composition of dipteran communities, while global richness remains the same, as has been observed for drosophilids in the northern Atlantic Forest of Brazil (Coutinho-Silva et al., 2017). This effect on richness is the result of a species turnover that reflects each group's climatic preference or tolerance. The pronounced seasonality (of temperature and rainfall) of the southern zone of the Neotropical region could have a direct influence on the structure of insect communities due to the different preferences or tolerances of their species to the climatic conditions (Battán Horenstein et al., 2012; Battán Horenstein & Gleiser, 2018).

Most studies on urban Diptera communities are usually focused on groups of economic importance (Stonehouse et al., 1998; Smiley et al., 2004; Taylor et al., 2012) or forensic-sanitary interest, like Culicidae (Alto & Juliano, 2001; Ludueña-Almeida et al., 2004; Gleiser & Zalazar, 2010; Mangudo et al., 2018), or saprophagous flies (Battán Horenstein et al., 2014, 2016; Dufek et al., 2019; Vilte et al., 2020), but relatively few of them were focused on the effects of seasonality on fly communities outside these groups of interest (e.g. Beckett, 1992; Valente-Gaieski, 2019). In Córdoba city, Battán Horenstein et al. (2012) and Battán Horenstein & Gleiser (2018), studied spatial-temporal patterns of necrophagous and saprophagous flies assemblages, and found a strong relationship between the abundance of some families and season. Culicidae in Córdoba city has been more closely studied (e.g. Almirón & Brewer, 1995; Gleiser & Zalazar, 2010; Pires & Gleiser, 2010; Grech et al., 2013), showing seasonality in the

occurrence and/or abundance of some species.

The main aim of the present study was to evaluate seasonal changes in adult Diptera assemblages of urban green patches in a southern temperate region. Our working hypothesis was that the environmental changes associated with each season induce alterations in the composition of Diptera assemblages in urban green patches of Córdoba city, due to the differential response of species to environmental conditions. Based on the dynamic equilibrium hypothesis (Huston, 1979; Laliberté et al., 2013), and assuming that urban green spaces are subject to disturbances, we predict that abundance and richness of flies will be lower in the winter (the low productivity season) compared to the summer (the high productivity season).

MATERIAL AND METHODS

Study area and sampling sites

The study area was Córdoba city (31°25'S; 64°11'W), Argentina (Fig. 1), which has historically been subjected to intense disturbance and modifications by human activities including deforestation, urbanization and agriculture. Located in the Espinal ecoregion (Cabrera, 1971), it is characterized by a temperate climate. The average annual precipitation ranges from 750 mm to 800 mm, and rainfall occurs mainly between October-December and March with water deficit during the winter (Capitanelli, 1979). Samplings were carried out in the summer (February) and winter (July) of 2014. That year, the mean temperature in February was 20.8 °C, with a maximum and minimum of 34.6 °C and 11.6 °C, respectively and rainfall was 269 mm. Mean temperature in July was 10.4 °C, ranging from a minimum -5.1 °C and a maximum 26 °C. July's precipitation was only 4 mm (National Meteorological Service).

Sampling sites (n = 15) were defined as 2,500 m. areas located within green spaces that ranged from naturalized vegetation-forest remnants to small urban parks (1 ha) (Fig. 1). Sites 1, 7 and 8 were open green spaces with patches of secondary growth of shrub vegetation and trees (native and exotic), with low to moderate human intervention (site 7 was in San Martín Urban Natural Reserve). Sites 2, 4, 11, 12 and 15 were approximately 1 ha plazas covered mostly by grassy areas, with scattered trees and few shrubs (usually ornamental species), suffering from high human intervention. Sites 3, 6, 9 and 13 were urban parks (> 3 ha) with moderate to high human intervention. The plazas had a higher proportion of concrete paths and impervious surface cover compared to parks. Sites 5 and 14 were lots with low maintenance vegetation (mixture of trees, shrubs and grasses). Site 10 was a

suburban premise mostly with open vegetation and vegetable crops.

Specimens were collected on each site using a garden-vacuum (G-VAC) method to suck insects from the vegetation, as described in Argañaraz et al. (2018). The vegetation in a square meter area was sucked during 1 min using a Sthil® vacuum cleaner with a 110 cm long and 12 cm wide tube. On each site and sampling period we collected ten subsamples, five from vegetation at ground level and five up to 200 cm above the ground. Ground level samples were always collected on vegetation patches, which may include relatively small patches of bare ground, but not from bare ground *per se*. Subsamples were scattered throughout each 2,500 m² area, with a minimum distance of approximately 10 m between two subsamples. In all, we collected 20 subsamples *per* site (300 total samples) during two seasons (10 subsamples on summertime-February 2014, and 10 on wintertime-July 2014), diurnally within 9 am - 5 pm. The pooled material collected from one site was considered as one sample unit (site) for data analysis. Samples were stored in ethanol 70% and flies were sorted in the laboratory under stereomicroscope (Leica Wild MZ8). All adult Diptera were identified to family based on morphological characteristics using taxonomic keys in McAlpine et al.

(1981). Higher rank taxa such as family of several groups (e.g. Diptera, Acari and Coleoptera) are considered useful surrogates of species diversity and indirectly of phenotypical and genotypical richness (Gaston & Williams, 1993; Martín-Piera, 2000; Báldi, 2003).

Data analysis

Number of families (richness), number of individuals (abundance) and taxonomic composition were estimated for the Diptera assemblages of summer and winter. Rarefaction curves (and 95% confidence intervals) were estimated for each season utilizing EstimateS 9.1.0 (Colwell, 2013). Two approaches were used to assess the global richness *per* season: rarefaction models based on individuals and rarefaction based on samples data. Individual based rarefaction models explicitly account for the relative abundance of families within the sample pool, while sample-based rarefaction curves account for patchiness in the occurrence of families (Colwell et al., 2004). We used two non-parametric estimators of family richness: Abundance-based Coverage Estimator or ACE (Chao & Lee, 1992) and Incidence-based Coverage Estimator or ICE (Lee & Chao, 1994). The sample coverage (C) estimated completeness of the sample while the coefficient of variation (CV) characterized the degree

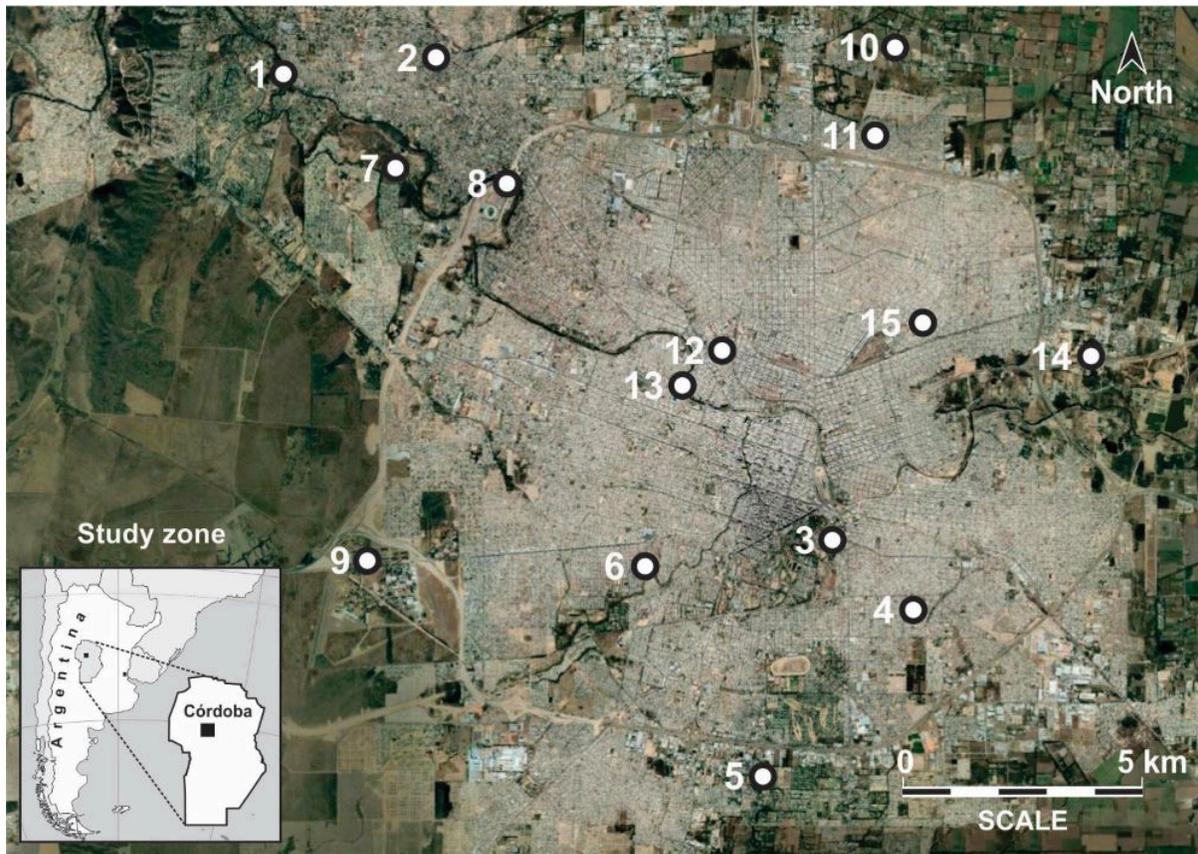


Fig. 1. Study area and location of sampling sites in Córdoba city, Córdoba province, Argentina.

of heterogeneity among families' discovery probabilities (SPADE; Chao et al., 2015).

Since comparisons of diversity may be influenced by the diversity index chosen, we also plotted the Renyi index diversity profiles of communities based on total samples from each season, to explore robustness of diversity ordering using PAST (Hammer et al., 2001). The conservative criteria of non-overlap of the 95% confidence intervals were considered to assess significant differences between profiles. With the same software, family rank-abundance curves were made, to establish which distribution model presented the best fit to observed data. To test this hypothesis, we used a Chi-Square test with $p \leq 0.05$ indicating lack of significant fit.

Seasonal family turnover was estimated using Simpson Index. A global estimation was made considering the total number of families in each season; the turnover *per* sampling site was also calculated. This index is based on presence-absence data. Simpson index = $\min(b, c) / [\min(b, c) + a]$; where a = number of families shared between seasons, b = total number of families that occur only in summer, and c = total number of families that occur only in winter. It ranges from 0 to 1, where 0 indicates that two communities share all families and 1 indicates that they are completely distinct (they do not share any families). This index depends on "a" and on the relative magnitude of "b" and "c", focusing on compositional differences rather than differences in species richness, thus it is recommended to measure turnover (Koleff et al., 2003).

In order to compare the abundance of Diptera between summer and winter, we used a Kruskal Wallis test (Infostat; Di Rienzo et al., 2008). A one-way ANOVA was used to compare family richness between the two sampling seasons. Differences in family composition between seasons were first explored with non-metric multidimensional scaling (NMDS), using the Bray-Curtis similarity index (PAST; Hammer et al., 2001), to ordinate dipteran community composition within different sites. Next, a PERMANOVA was performed using the same software. To do this, an abundance matrix (transformed to $\ln(n+1)$) was made. Due to the significant difference that resulted from this test, we continued with a SIMPER analysis using a Bray-Curtis similarity index matrix, to determine each family' contribution to the dissimilarities between seasons.

RESULTS

Global community analysis

A total of 1,802 adult Diptera were collected in winter, from which 1,756 were assigned to 30 families (46 specimens were in bad shape and could not be identified). In summer, 7,236 dipteran specimens were collected from which 7,201 were assigned to 32 families. Individuals that could not be identified constituted a

small percentage of the sample (< 2.7%) and were excluded from analysis. The most abundant families in summer were Chloropidae and Cecidomyiidae, representing together 57% of the total sample, while in winter, Chironomidae and Chyromyidae were more frequent (51% of the sample) (Table I).

Both individual based and sample based rarefaction curves (Fig. 2) showed that there were no statistically significant differences between the global richness of each season. These curves and C values close to 100% indicate a good representation of families in the samples and a very low probability of finding new families if more samples were collected. The CV values for each of the two seasons indicate high heterogeneity in family discovery probabilities in the samples (Table II).

There were no significant differences between diversity profiles of the total specimens collected in summer and winter or significant line crosses between the two, indicating that dominance patterns were similar between seasons (Fig. 3).

To globally describe the structure of the Diptera community in terms of proportional abundance of each family, rank-abundance models were analyzed. The log-normal model fit best the distribution of the data in both summer ($p = 0.42$) and winter ($p = 0.86$) (Fig. 4). This model represents a situation in which the logarithms of the abundances of the different families follow a Gaussian distribution and as such it characterizes a community with relatively few very abundant or very rare species (Matthews & Whittaker, 2014). The geometric, logarithmic and broken-stick models were not appropriate ($p < 0.0001$). The Simpson global index was 0.33, which can be interpreted as a moderate to high similitude in the family composition between the seasons.

Community analysis per site

On average, the number of specimens collected in summer was significantly higher (four times higher) than in winter ($p = 0.0005$) (Fig. 5a). There were significant differences in mean richness of families *per* site between seasons, also being higher in the summer ($F_{1,28} = 31.80$; $p < 0.0001$) (Fig. 5b).

The mean Simpson index was 0.34 ± 0.08 , indicating a moderate turnover of families between seasons. The NMDS shows two groups of data that represent each season, without overlap (Fig. 6). According to a PERMANOVA, the family assemblages of summer and winter differed significantly ($F = 9.52$; $p = 0.0001$). The average dissimilarity (as *per* SIMPER) was 69.16%.

Table III shows the contribution of each family to the dissimilarity between seasons. Eight families were responsible for 50% of the differences between summer and winter, explained in general by their lower relative abundances in winter.

Family	Season					
	Summer			Winter		
	Individuals (n)	Sites with presence (%)	Relative abundance (%)	Individuals (n)	Sites with presence (%)	Relative abundance (%)
Chloropidae	2417	100	34	201	73	11
Cecidomyiidae	1682	100	23	7	33	<1
Chironomidae	1087	100	15	624	87	36
Sciaridae	367	100	5	69	67	4
Phoridae	269	93	4	60	60	3
Ceratopogonidae	221	100	3	122	33	7
Scatopsidae	194	80	3	0	0	0
Chyromyidae	162	73	2	256	80	15
Heleomyzidae	136	67	2	219	73	12
Empididae	133	87	2	0	0	0
Sphaeroceridae	81	80	1	6	20	<1
Drosophilidae	69	80	1	5	20	<1
Sarcophagidae	65	80	1	0	0	0
Mycetophilidae	61	53	1	0	0	0
Culicidae	48	80	1	0	0	0
Ephydriidae	43	47	1	24	60	1
Agromyzidae	37	60	1	17	40	1
Dolichopodidae	35	67	<1	1	7	<1
Muscidae	27	53	<1	39	53	2
Tephritidae	13	53	<1	7	27	<1
Psychodidae	11	33	<1	0	0	0
Lauxaniidae	10	33	<1	10	27	1
Anthomyiidae	5	27	<1	10	7	1
Simuliidae	4	13	<1	13	13	1
Camillidae	0	0	0	27	40	2
Dryomyzidae	0	0	0	15	27	1

Table I. Diptera families collected in 15 green urban patches of Córdoba city, in summer and winter. Families with fewer than five specimens are listed below: Families with fewer than five individuals in both seasons: Summer and winter: Tachinidae and Chamaemyiidae. Summer only: Micropezidae, Sepsidae, Stratiomyidae, Syrphidae, Tipulidae, and Pipunculidae. Winter only: Anthomyzidae, Calliphoridae, Otitidae, Scatophagidae, Carnidae, Canacidae, Perisclididae, and Synneuridae.

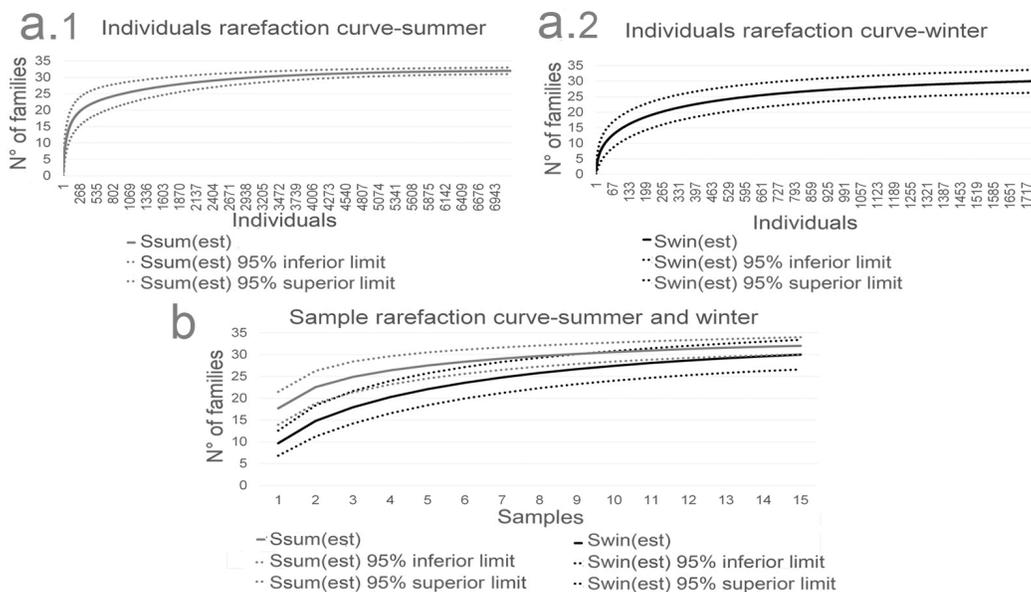


Fig. 2. Families' rarefaction curves per season. a. Individual rarefaction curves. b. Sample rarefaction curves. Pointed lines represent 95% confidence intervals. Swin= winter estimated richness; Ssum= summer estimated richness.

	Season			
	Abundance		Incidence Frequency	
	Winter	Summer	Winter	Summer
Number of individuals / Number of samples	1756	7201	15	15
Number of families	30	32	30	32
Estimated coverage (C)	0.99	1	0.96	0.99
Estimated CV	2.13	2.31	0.73	0.57
ACE / ICE	32.49 ± 2.53	32.39 ± 0.81	34.21 ± 3.39	33.62 ± 1.88

Table II. Estimated cover (C), coefficients of variation (CV) and richness estimators' values (ACE/ICE) for summer and winter assemblages, according to abundance and family incidence frequency. ACE = Abundance-based Coverage Estimator. ICE = Incidence-based Coverage Estimator.

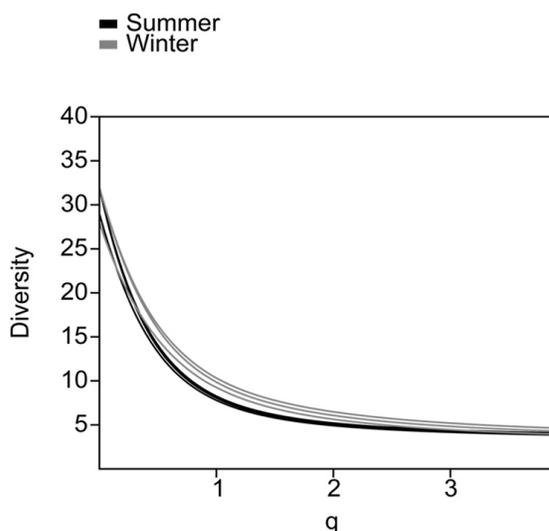


Fig. 3. Diversity profiles based on total summer and winter samples. Pointed lines represent 95% confidence intervals.

DISCUSSION

Families' rarefaction curves and estimated coverage (C) in both seasons show that the data gathered is representative of the Diptera assemblages that may be collected with the G-VAC technique. The diversity profiles reflect a similar global diversity between seasons (*i.e.*, dominance patterns do not change seasonally).

Both communities fit a log-normal distribution model, the most common in biological communities which tends to be associated with stable or not disturbed systems (Hill & Hamer, 1998). Other studies in tropical regions found fly communities (focusing on one family) that fit the same distribution model in low disturbance systems such as rivers and different mesoregions from Brazil (Simião-Ferreira et al., 2009; Sousa et al., 2015).

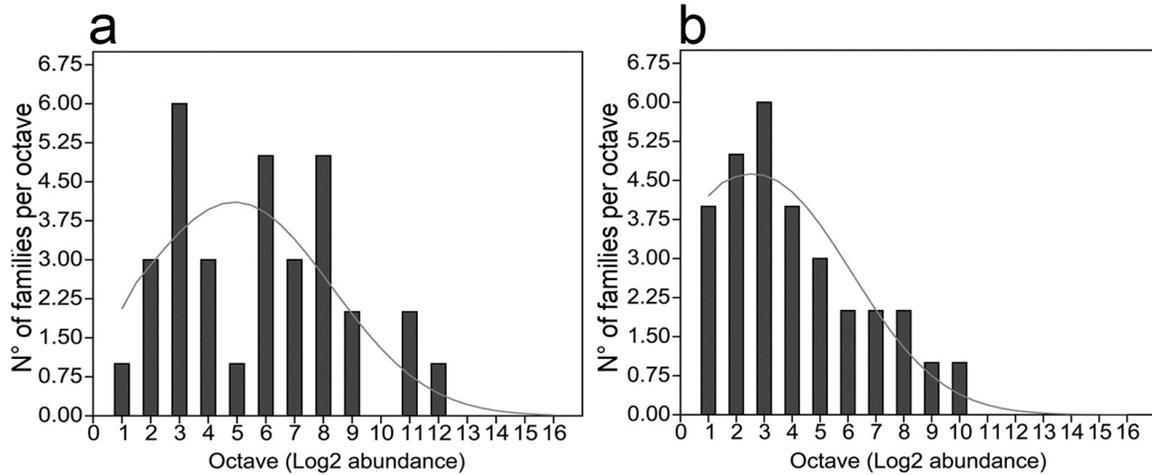


Fig. 4. a. Summer rank-abundance curve (log-normal). b. Winter rank-abundance curve (log-normal).

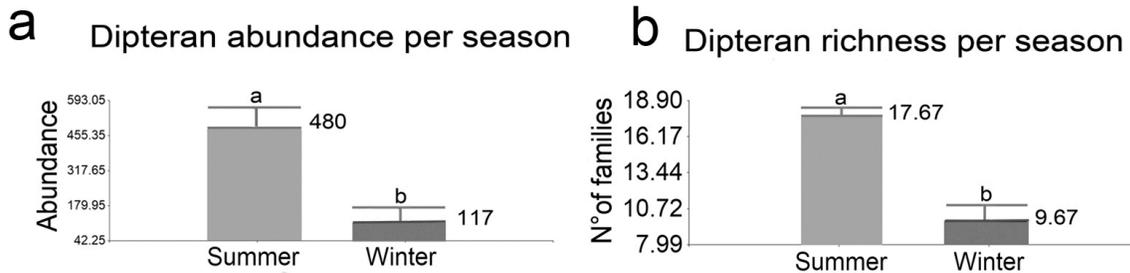


Fig. 5. a. Average dipteran abundance *per* season. b. Average dipteran richness *per* season. a-b different letters indicate statistically significant differences ($p < 0.001$).

Dipteran adults of temperate habitats (mostly in studies from the northern hemisphere) tend to be more abundant during spring/summer and less abundant during autumn/winter (Wolda, 1988). Consistently, the number of Diptera that we captured in the summer was considerably higher than in the winter. Global richness was the same in both seasons, but we found significant differences in dipteran richness when considering the diversity *per* site, suggesting that in winter, the family distribution was more heterogeneous than in summer. During the warm season, all sites presented a high number of individuals and families, while in winter some sites had very low abundance and richness. The fluctuations in abundance and the differences between taxa are probably a result of multiples processes, biotic and abiotic (Pinheiro et al., 2002), so it is not always possible to determine the cause of variations in the community.

Approximately a third of the families that were present in the summer were replaced by others in the winter. This could be due to a differential response to environmental conditions from the members of these groups, as was

observed in other studies on specific families (Beckett, 1992; Souza & Linhares, 1997; Mulieri et al., 2011). Most notably, 12 families were only detected in the summer and 10 only in the winter. In summer, we collected several individuals of Scatopsidae, Empididae, Sarcophagidae, Mycetophilidae and Culicidae, but none were present in winter samples. This is consistent with other studies on the seasonality of these families (Peng et al., 1994; Lambkin et al., 2011; Mulieri et al., 2011; Fremdt & Amendt, 2014; Chatelain et al., 2018). The predatory habit of groups like Empididae could explain their seasonal dynamics. During the cold and dry season, food availability decreases and as a result their population decreases in abundance. Some studies focused on species of Culicidae of sanitary interest in Córdoba province (Almirón et al., 2000; Fava et al., 2001) observed active individuals of some species such as *Aedes (Ochlerotatus) albifasciatus* during the cold period; the abundance of this species is correlated with precipitation and rainfall frequency (Gleiser et al., 2000). In this study, Culicidae was not collected in winter, which could be due to July's low precipitation (4 mm that year).

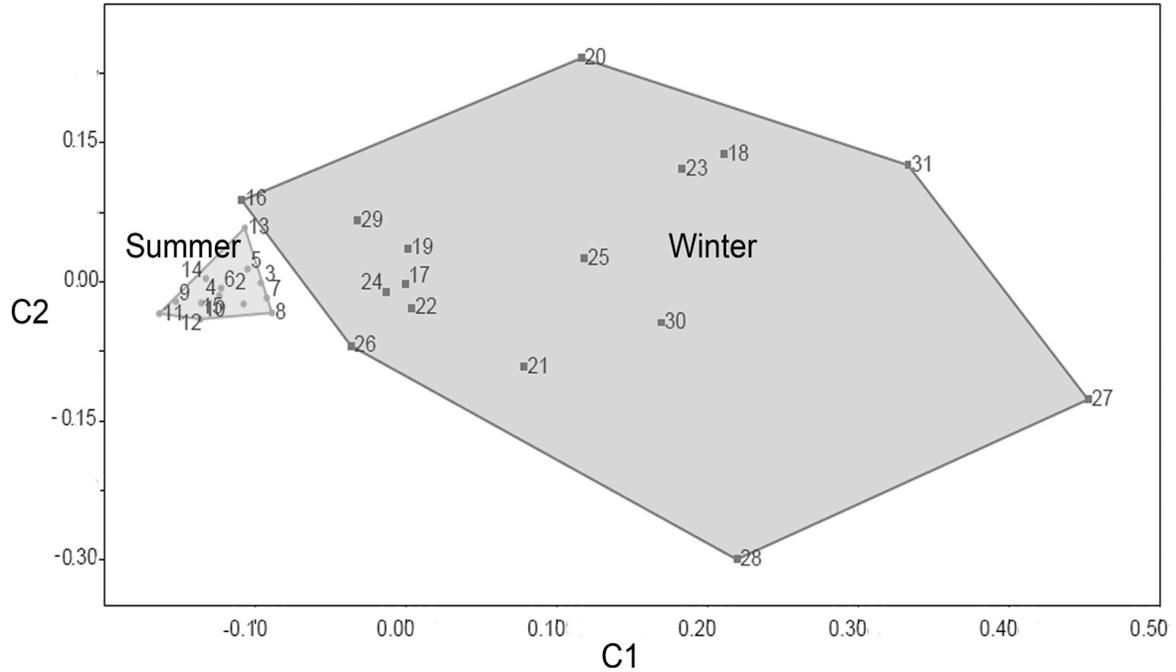


Fig. 6. Non-metric multidimensional scaling of dipteran assemblages in Córdoba city. Abundance transformed to Ln (n+1).

Taxon	Mean dissimilarity	Contribution %	Accumulated %	Mean Summer	Mean Winter
Cecidomyiidae	7.29	10.54	10.54	4.04	0.28
Chloropidae	6.64	9.61	20.15	4.64	1.53
Chironomidae	4.42	6.39	26.54	3.71	2.14
Ceratopogonidae	3.96	5.73	32.27	2.27	0.63
Scatopsidae	3.85	5.57	37.84	1.93	0
Sciaridae	3.84	5.56	43.39	2.97	1.24
Phoridae	3.47	5.01	48.41	2.51	1.10
Empididae	3.06	4.43	52.84	1.61	0

Table III. SIMPER analysis of family contributions to dissimilarities between summer and winter assemblages (abundance data transformed to Ln (n+1)). Only families that explain approximately an accumulated 50% of the differences between seasons are listed.

In winter, several individuals of Camillidae and Dryomyzidae were collected, but none were present in the summer sampling. This could be the first record of these families' preference for winter conditions, as we could not find seasonal information on them.

Although on average the number of families *per* site decreased in winter, in some sites, richness remained the same between seasons. Some sites experienced a big turnover from summer to winter (e.g. half of the present families changed) while in others the composition remained similar. Higher changes may be related with resource availability during the low production season: Plazas, typically smaller green spaces with lower plant cover and higher human intervention (n =5), showed a 53 to 86% decrease in the number of families detected between seasons. On the other hand, in most forest patches, lots and parks (8 of 10 remaining sites), richness did not change or decreased higher than 47% from summer to winter. Two sites with high vegetation cover and low human intervention (sites 7 and 14) showed a moderate reduction of 64 and 67%, which may be due to site-specific ecological characteristics that should be further explored.

The contrasting pattern of abundance and richness between seasons could be due to a source-sink dynamic (Pulliam, 1988). Species living in highly fragmented landscapes often occur as metapopulations, in which the local population turns over quite frequently, but the metapopulation (population of populations) tends to persist (Hunter, 2002; Hanski & Gaggiotti, 2004). Source-sink dynamics are based upon high quality patches (birth exceeds death, emigration exceeds immigration) supporting populations in low quality patches (death exceeds births, immigration exceeds emigration) (Hunter, 2002; Hanski & Gaggiotti, 2004). It is possible that those sites with fewer individuals and low richness during winter, such as plazas, are sink patches for some families. In summer, when the conditions are beneficial, some sites such as larger parks and forest patches, will act as a source and support bad quality patches populations. Then in winter, when the environmental conditions worsen, dispersal decreases and as a result a series of local extinctions occur on sink sites. Frouz & Kindlmann (2001) registered a source-sink type dynamic in some terrestrial Chironomidae species. They determined the existence of source habitats that provided good quality food for Chironomidae larvae but were also very sensitive to summer desiccation. This often resulted in extinction of the summer larval population, followed in winter by re-colonization from less suitable, but more stable "sink" habitats in the surrounding landscape.

The NMDS, which considers not only presence but also the abundance per site of each family, showed a clear difference in the composition of the assemblages from each season, which were statistically significant in PERMANOVA. Eight families (Cecidomyiidae, Chloropidae, Chironomidae, Ceratopogonidae, Scatopsidae, Sciaridae,

Phoridae and Empididae) were responsible for 50% of the differences between seasons, explained in general by their lower relative abundances in winter.

Very few specimens of Cecidomyiidae were found in the winter. Most studies on the seasonal dynamics of this family are focused on species of economic importance (some are pests) and register the emergence of adults on spring/summer and larvae hibernation during the cold period (Orphanidaes, 1975; Baxendale & Teetes, 1983; Doane & Olfert, 2008). Since we only sampled the adult populations, this could also be the case for urban species of this family.

Although the relative abundance of Chloropidae was lower in the winter compared to summer, it was one of the most abundant families during the winter. Kitching et al. (2005) observed an increase in Chloropidae abundance during the winter and suggested this could be because most of the species that belong to this group are not predators or complete aquatic decomposers, so the resources that they need are present even during the cold and dry season. Lambkin et al. (2011) also found Chloropidae active during the winter which was attributed to their feeding habits (as suggested by Kitching et al. (2005)) and use of habitat.

Chironomidae, on the other hand, was more than twice more abundant in the summer than in the winter but its relative abundance was higher during the cold period. Immature stages of Chironomidae are usually found in aquatic or semi-aquatic environments (McAlpine et al., 1981) so it is possible that this family's populations are benefited by humid summer conditions, while lying dormant in the dry winter. Larvae of this group have several drought resistance strategies (Frouz et al., 2003) and Beckett (1992), while studying the phenology of nearctic Chironomidae larvae, observed an almost complete change in this family's community composition between summer and winter. Some species that belong to this group are multivoltine or bivoltine (Oliver, 1971; Pinder, 1986), which would explain adult presence both in winter and summer. Also, we collected Chironomidae adults only in some sites in the cold and dry season, while in summer they were present in all sampling sites. We could be observing something similar to the recolonization by adults after dry season larvae extinction registered by Frouz & Kindlmann (2001) but we cannot be sure as we did not collect larvae of any family.

The same pattern as Chironomidae was observed for Ceratopogonidae, which was almost twice as abundant in summer than in winter, but its relative abundance was slightly higher in the cold season. This is consistent with other studies within the family (Murray, 1991; Szadziewski et al., 1997; Ander et al., 2012; Santiago-Alarcon et al., 2013; Cazorla & Campos, 2019). Among the Ceratopogonidae there are both univoltine and multivoltine species and most biting midges overwinter as larvae or eggs (Szadziewski et al., 1997). Larvae develop in moist habitat such as rotting vegetation, semiaquatic or aquatic habitats such

as phytotelmata (Borkent & Spinelli, 2007; Díaz et al., 2019). Murray (1991) found that some breeding continued throughout the winter and Walker (1977) determined that many species of this group would persist in stable populations throughout the year even when rain was scarce. Recently, in an urbanization gradient on northeastern Buenos Aires (Argentina), a lower species richness was recorded in the winter compared to warmer seasons; however, the variations in the Ceratopogonidae community were related with relative humidity and rainfall rather than with temperature (Cazorla & Campos, 2019). The reason that these two families were relatively more abundant in winter is that other families were probably not as tolerant to the changes in environmental conditions and some were extremely successful during the summer, achieving higher numbers of individuals that season.

Other families did not show relevant seasonal changes, as has been observed by others (Steffan, 1966; Peng et al., 1994; Folgarait et al., 2003; Nielsen & Nielsen, 2004; Lambkin et al., 2011; Battán Horenstein et al., 2012; Chatelain et al., 2018). This may indicate that they are somewhat tolerant to changes in climatic conditions. On the other hand, the seasonal turnover may occur at a taxonomic level lower than family.

The data collected reflect seasonal variations in the relative abundances and family composition of adult stage dipterans on vegetation. Since sampling took place during the daytime, those specimens either active or resting on the vegetation were collected, but species that may be active during the evening and resting in crevices or other sheltering sites during the day were probably underestimated in the samples.

In conclusion, even though the total number of families of flies was similar between the two analyzed seasons, richness *per* site was significantly higher in the summer as families' spatial distribution was more heterogeneous in the winter. Family composition and/or their relative abundances differed between summer and winter assemblages.

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