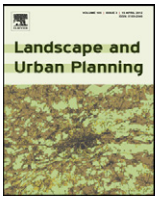
Landscape and Urban Planning 105 (2012) 288–295

Contents lists available at SciVerse ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan



Community structure of artificial container-breeding flies (Insecta: Diptera) in relation to the urbanization level

Alejandra Rubio[a], María Isabel Bellocq[b], Darío Vezzani[a,*]

[a] Unidad de Ecología de Reservorios y Vectores de Parásitos, Departamento de Ecología, Genética y Evolución, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Ciudad Universitaria, Pabellón 2, 4° piso, (C1428EHA) Buenos Aires, Argentina

[b] Ecología de Comunidades y Macroecología, Departamento de Ecología, Genética y Evolución, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Ciudad Universitaria, Pabellón 2, 4° piso, (C1428EHA) Buenos Aires, Argentina

ARTICLE INFO

Article history:
Received 16 August 2011
Received in revised form
20 December 2011
Accepted 7 January 2012
Available online 1 February 2012

Keywords:
Community structure
Biodiversity
Urban environment
Culicidae
Chironomidae
Insect conservation

ABSTRACT

The changes in the community structure of flies breeding in small artificial containers along environments of different urbanization level were assessed at two spatial scales; i.e. patch and landscape. A total of 8400 water-filled flower vases were inspected in 14 cemeteries from temperate Argentina. A total of 267,013 larvae were collected in 31.1% of the inspected containers. Twenty-four species belonging to eleven Diptera families were identified. Four species (from Muscidae, Culicidae, Chironomidae, and Ceratopogonidae) represented 95.6% of the larvae collected and 93.2% of the occupied containers. For the local spatial scale, i.e. patches within cemeteries, there was no evidence that the community structure differs between open green spaces and densely built areas. For the landscape spatial scale, i.e. among cemeteries surrounded by different urbanization levels, different patterns were detected. The percentage of containers harboring larvae and the abundance (total and per container) showed a clear peak at intermediate levels of urbanization (20–40% of impervious area). The species richness and composition were similar along the gradient. Our results suggest that the urbanization level affects the studied community depending on the spatial scale.

1. Introduction

Urbanization is a growing process worldwide. The urban expansion resulting from the continuous population growth leads to a gradual transformation from native or rural habitats into landscapes of increasing impervious areas (i.e. built cover). Thus, the urban sprawl affects biodiversity, promoting changes in the structure of animal and plant communities (Smith, Gaston, Warren, & Thompson, 2006). Growing urbanization have been associated with declines in local species richness and general abundance, increases in relative abundance of species tolerant to disturbance and shifts in composition of animal and plant assemblages (Hansen et al., 2005; McKinney, 2008). South America is not exempt to the biodiversity loss associated to the urbanization process (Pauchard, Aguayo, Peña, & Urrutia, 2006). In the megalopolis of Buenos Aires (Argentina), which is the second largest urban agglomeration of Latin America (UNDP, 2009), the association between urbanization and animal communities were previously studied for rodents and birds (Cavia, Cueto, & Suarez, 2009; Faggi, Krellenberg, Castro, Arriaga, & Endlicher, 2008; Garaffa, Filloy, & Bellocq, 2009).

Urban gradients can capture the entire range of urban effects (Pickett et al., 2001) and offered an effective framework to study the effects of urbanization on invertebrates (McIntyre & Rango, 2009; McKinney, 2002). Specifically, arthropods have served as useful models for testing several aspects of human-environmental changes because they are diverse and easy to sample, have short life cycle and are relevant to human health and economy (McIntyre, Knowles-Yánez, & Hope, 2000; McKinney, 2002). Studies analyzing arthropod communities in urban environments have focused mainly on terrestrial assemblages (e.g. Alaruikka, Kotze, Matveinen, & Niemelä, 2002; McIntyre & Hostetler, 2001). Among urban aquatic assemblages those of streams have received considerable attention (Paul & Meyer, 2001), and immature mosquitoes (Diptera: Culicidae) have been the most studied due to their importance as vectors of diseases (e.g. Cox, Grillet, Ramos, Amador, & Barrera, 2007; Leisnham, Lester, Slaney, & Weinstein, 2006). Among the wide range of aquatic habitats used by mosquitoes (see Service, 1995), artificial or man-made containers, such as water tanks and flower vases, are particularly widespread in urban areas. Although other Diptera families have been included in some studies dealing with artificial containers-breeding species (e.g. Ebeling, 1975; Hribar et al., 2004), the effect of urbanization on the entire fly community remains poorly studied, either in artificial containers as in others aquatic habitats. Understanding how flies respond to urbanization at different scales can improve management strategies of

---

* Corresponding author. Tel.: +54 11 4576 3354; fax: +54 11 4576 3354.
E-mail addresses: alerrubio@ege.fcen.uba.ar (A. Rubio), bellocq@ege.fcen.uba.ar (M.I. Bellocq), vezzani@ege.fcen.uba.ar (D. Vezzani).

0169-2046/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.landurbplan.2012.01.009

Table 1
Geographical location, size, and percentage of surface occupied by graves (GRV) and mausoleums (MSL) in each cemetery included in the study.

District	Cemetery coordinates	Size (ha)	Percentage of surface GRV/MSL	Number of monthly samples in GRV/MSL
Berazategui	34°47′26.82″S 58°11′0.97″W	25.8	100/0	200/0
San Isidro	34°29′34.96″S 58°34′46.92″W	12.8	85.2/14.8	170/30
Cañuelas	35°3′19.02″S 58°47′43.01″W	3.9	25/75	50/150
Esteban Echeverría	34°51′17.93″S 58°28′40.50″W	11.1	91.7/8.3	183/17
Escobar	34°19′43.51″S 58°47′52.08″W	6.3	93.1/6.9	186/14
Giles	34°25′23.11″S 59°26′52.80″W	5.2	71.1/28.9	142/58
Gral Las Heras	34°54′47.07″S 58°56′43.83″W	3.8	64.7/35.3	129/71
Mercedes	34°40′20.50″S 59°27′56.40″W	4.5	45.2/54.8	90/110
Morón	34°39′44.80″S 58°37′38.00″W	11.9	42.2/47.8	104/96
Quilmes	34°44′39.40″S 58°13′30.81″W	23	63.5/36.5	127/73
Gral San Martín	34°35′3.82″S 58°33′1.50″W	14	89.6/10.4	179/21
Tigre (Benavides)	34°25′32.90″S 58°42′20.97″W	5.4	95.6/4.4	191/9
Tigre (Downtown)	34°25′54.01″S 58°34′45.05″W	3.8	88/12	176/24
San Fernando	34°27′26.09″S 58°33′9.97″W	8.6	76.7/23.3	153/47

nuisance species (e.g. mosquitoes as disease vectors) and simultaneously help to the conservation of potentially useful species (e.g. chironomids as bioindicators) in urban areas.

The fauna of urban green areas (i.e. parks, gardens, vacant lots) is better known than that of impervious areas (McIntyre et al., 2000; Pickett et al., 2001; Smith et al., 2006). Cemeteries, a mandatory component of human settlements around the world, combine features of green and impervious areas and have been described as ideal settings to perform ecological studies in urbanized areas (Vezzani, 2007). In addition, cemeteries are characterized by an extremely high availability of flower vases that can serve as habitats for aquatic stages of flies. Here, we investigate the structure of the Diptera community occurring in artificial containers in environments of different urbanization level. Specifically, we assessed changes in community attributes at two spatial scales, between patches of different edification level within cemeteries and among cemeteries placed along an urbanization gradient.

2. Materials and methods

2.1. Study area

The study was conducted in Buenos Aires Province, which is located in the Pampean region where urban and rural (agriculture and pastoral farming) land uses have been developed in highly productive lands (Matteucci & Morello, 2009). The climate is temperate with annual mean temperature averaging 14–17 °C and annual precipitation ranging from 600 to 1200 mm (Magrin, Travasso, Díaz, & Rodríguez, 1997). The study area embraced the Greater Buenos Aires (GBA) and four neighboring rural districts (Cañuelas, Giles, Gral Las Heras and Mercedes) located approximately 100 km from Buenos Aires city. GBA covers 3827 km^2 and has the greater population density of Argentina (3345 inh/km^2) (INDEC, 2010).

The surveys were conducted in 14 public cemeteries (Table 1) located from highly urbanized areas of GBA to small rural localities. Sampled cemeteries were larger than 3 ha and located at least 3-km apart (range: 3.7–118.1 km). Internally, cemeteries have two main patch types easily distinguishable and related to burial traditions (Vezzani, 2007). Graves (GRV) are placed in open spaces characterized by a matrix of grass accompanied by bushes and trees and a few man-made structures. In contrast, mausoleums (MSL) are characterized by high coverage of impervious area and scarce or no vegetation cover. The proportion of the area occupied by GRV and MSL in each cemetery was quantified using Google Earth software 4.3 and further checked by ground proofing.

2.2. Data collection and insect identification

Samples were collected in the 14 cemeteries during October 2007 (spring), January 2008 (summer) and April 2008 (autumn). In each cemetery and sampling period, 200 flower vases with water were randomly selected and inspected, collecting a total of 8400 samples. The number of samples taken in GRV and MSL was proportional to the area occupied by both patch types (see Table 1). To account for all immature flies present in each vase, water was filtered with a fine mesh strainer and the resulting sample was immediately fixed in 70% ethanol. Total capacity of each container surveyed was recorded as representative of container size. Water volume contained was also measured for further estimation of immature fly densities.

Only larvae were considered in the analysis because of the complexity of pupae identification. Third and fourth instar larvae of Culicidae were identified to species using dichotomical keys (Darsie, 1985; Rossi et al., 2002). Larvae of Chironomidae were identified to genera (Epler, 2001; Wiederholm, 1983) and larvae of other Diptera to family (McAlpine et al., 1981) and further to morphospecies.

2.3. Data analysis

Dipteran community was characterized through the percentage of water-filled containers harboring larvae (CI: container index), the number of collected individuals (TA: total abundance), the number of individuals per infested container (DC: density per container) and per liter (DL: density per liter), the number of species (S: species richness) and the species composition (SC). The variable CI represents the proportion of occupied habitat, whereas DC and DL reflects the intensity of use of each container.The changes in community attributes according to the urbanization level was assessed at both scales, the local or patch (i.e. GRV versus MSL within cemeteries) and the landscape (i.e. cemeteries located along the urbanization gradient). For both approaches, community attributes were explored for each sampling season and pooled for an overall analysis.

2.4. Local scale

At the local scale, CI, S, DC, DL and SC were compared between GRV and MSL patches. CI was compared with the chi-squared test for two independent proportions (Fleiss, Levin, & Paik, 2003). S was compared using rarefaction curves and confidence intervals according to Magurran (2004). As this method includes the relative abundance of the species in the calculations, the results could be interpreted as a measure of diversity (Buddle et al., 2005). The

Table 2
Attributes of dipteran community found in flower vases of cemeteries from Buenos Aires Province in each season.

	Spring	Summer	Autumn
Container index (CI)	15.4%	32.5%	45.4%
Total number of individuals (TA)	32,681	104,034	130,298
Number of species (S) and families	19/7	16/8	12/8
Median and quartiles of individuals per container (DC)	18 (3–69)	31 (8–85)	23 (6–82)
Median and quartiles of individuals per liter (DL)	60 (12–182.9)	160 (33.3–500)	100 (22.9–380)
Species composition (SC)			
Fam. Culicidae			
Aedes aegypti	•	•	•
Culex pipiens	•	•	•
Culex eduardoi	•	•	
Fam. Ceratopogonidae			
Morphospecies 1	•	•	•
Fam. Chaoboridae			
Morphospecies 1			•
Fam. Chironomidae			
Tanytarsus sp.	•		
Chironomus sp. 1	•	•	•
Chironomus sp. 2	•	•	
Limnophytes sp.	•		
Pseudosmittia sp.	•		
Fam. Ephydridae			
Morphospecies 1	•		
Morphospecies 2			•
Fam. Muscidae			
Morphospecies 1	•	•	•
Morphospecies 2	•	•	
Morphospecies 3	•	•	•
Morphospecies 4	•	•	
Morphospecies 5	•	•	•
Fam. Psychodidae			
Morphospecies 1	•	•	•
Morphospecies 2	•	•	•
Morphospecies 3	•		
Fam. Sarcophagidae			
Morphospecies 1		•	
Fam. Stratiomyidae			
Morphospecies 1		•	
Fam. Syrphidae			
Morphospecies 1		•	•
Fam. Tipulidae			
Morphospecies 1	•		

medians of DC and DL were compared between patch types with the Mann–Whitney *U*-test (Siegel & Castellan, 1995). Similarity in SC was estimated by the Sörensen index (Magurran, 2004), and was interpreted according to Krebs (1989) as follows: $\leq$0.39 means low similarity, 0.4–0.49 moderate, 0.5–0.59 high and $\geq$0.6 very high. Finally, the median capacity and median water volume of containers found harboring immature flies in GRV and MSL were also compared with the Mann–Whitney *U*-test.

2.5. Landscape scale

At the landscape scale, the urbanization level of the neighborhood of each cemetery was quantified using a Landsat 5 TM satellite image captured in January 22, 2010. A non-supervised classification was made to identify impervious areas such as paved roads and concrete structures using Erdas Imagine 8.4 software. The percentage of impervious area (PIA) was calculated in a circle of 1 km radius centered in the geometric center of each cemetery using GIS-ArcView 3.2. We assume that the surface occupied by each cemetery within this circle did not affect considerably the estimation of PIA because it was lower than 8.5% in all cases. Then, to assess if the estimated PIAs reflect the intensity of human use, a Pearson correlation (Zar, 1999) between the natural logarithm of PIA and the number of dwellings in the corresponding district (INDEC, 2010) was performed; each apartment or stand alone house was considered a dwelling.

To analyze community responses to increasing urbanization, simple regression analyses were performed using PIA as independent variable and CI, TA, DC, DL, S and SC similarity as response variables (Zar, 1999). Regression assumptions were tested for every analysis. S values were estimated by the rarefaction curves considering the abundance level of the smaller community (Magurran, 2004). SC similarity was estimated by the Sörensen index comparing each cemetery with the most rural (i.e. Giles), and the values obtained were interpreted following Krebs (1989) as was already explained for the former spatial scale. The relationship between community and landscape structures can be masked by spatial autocorrelation of the studied sites. Therefore, a Mantel test (Legendre & Legendre, 1998) was used to evaluate the correlation level between the matrix of dissimilarity of the sites based on species composition and the matrix of geographic distance between the sites (1000 permutations). Finally, Spearman's non-parametric correlation coefficients were calculated to determine relationships between those variables that resulted statistically significant in the regression analysis (Zar, 1999).

3. Results

3.1. General findings

Out of 8400 water-filled containers examined, 2610 harbored dipteran larvae (CI = 31.1%). The median DC was 25 individuals

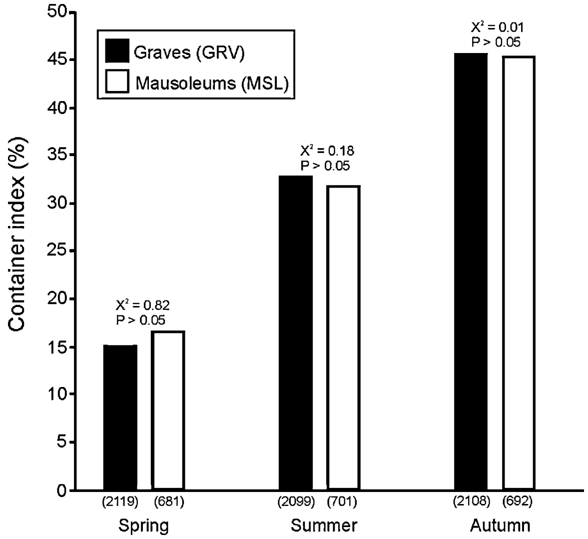


Fig. 1. Statistical comparison of the container index (CI) between patch types according to the sampling season; sample size within brackets.

(quartile [q]1 = 6, q3 = 81) and the median DL was 107.5 individuals (q1 = 22.5, q3 = 380). A total of 267,013 individual dipterans representing 24 species and eleven families were collected during the study period (Table 2). Four of these families concentrated 97% of the individuals collected, with one dominant species per family; (Muscidae) morph. 1: 44%, (Culicidae) *Culex pipiens*: 36%, (Chironomidae) *Chironomus* sp. 1: 10%, and (Ceratopogonidae) morph. 1: 6%. In accordance, these four fly species were represented in 93% of the occupied containers.

Regarding seasonality, CI and TA showed a clear increasing trend throughout the sampling seasons whereas S followed the opposite pattern (Table 2). On the other hand, DC and DL recorded higher values in summer. In addition to those four most abundant species, other five species were found throughout the entire study period, and ten species were recorded only in one season (Table 2).

3.2. *Responses at the local scale*

The overall CI did not differ significantly between patch types (GRV: 31%; MSL: 31.2%; $X^2_{(1)} = 0.04$, $P = 0.85$), and similar results were observed in each sampling season (Fig. 1). Likewise, the rarefaction curves showed overlaps between the estimated S for GRV and MSL and the confidence limits of the other for all seasons (Fig. 2), indicating no statistical differences between patches. The Sörensen index revealed a very high similarity in SC between both patch types (spring: 0.73; summer: 0.72; autumn: 0.86; overall: 0.77). Fifteen species were recorded in both patch types. These were all the species of Culicidae, Muscidae, Psychodidae, Syrphidae and two of Chironomidae. Of the remaining species, seven were collected exclusively in GRV and two in MSL.

The unique attribute that differed significantly between patches was DC, which was about twice higher in GRV than in MSL through the seasons (Fig. 3). However, the capacity of occupied containers and the water volume contained were also significantly higher in GRV than in MSL (Fig. 4). Therefore, it could be assumed that DC was higher in GRV just because the containers were larger and contained more water, but not due to intrinsic effects of the environment. This explanation was supported by the fact that DL showed no differences between patches, except for a marginal difference in autumn (Fig. 3).

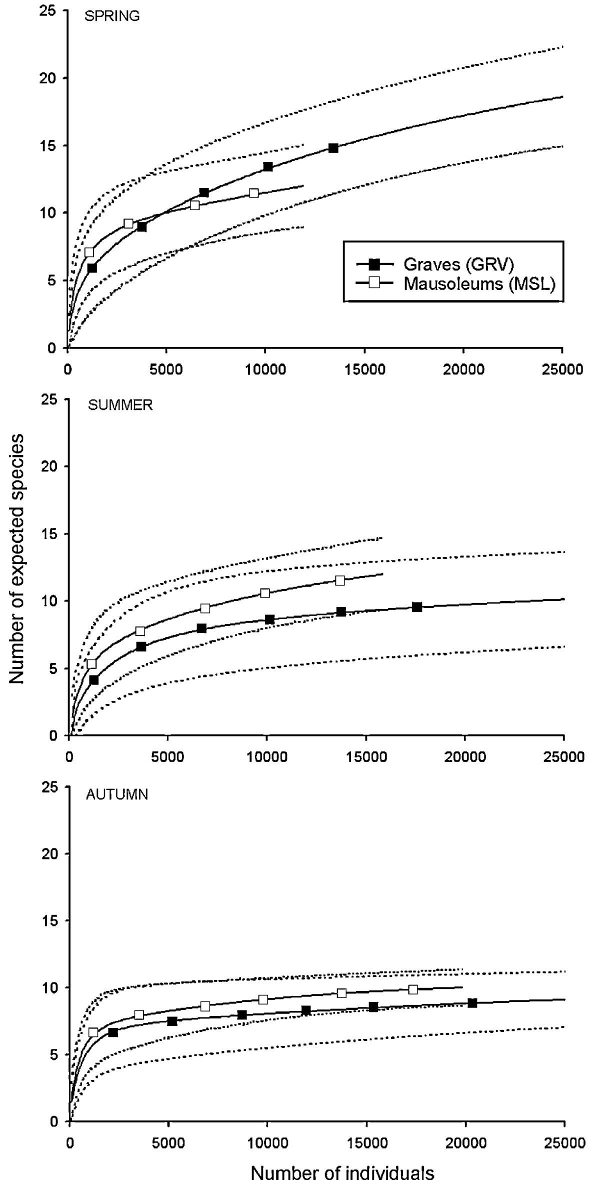


Fig. 2. Rarefaction estimates of the expected richness (filled line) and 95% confidence intervals (dotted line) in both patch types according to the sampling season.

In brief, there was no evidence to support the idea that the structure of the studied Diptera community differs between these contrasting environments within cemeteries.

3.3. *Responses at the landscape scale*

The estimated PIA ranged from 1.2% to 86.5%, covering almost the entire urbanization gradient. In addition, the Ln PIA was positive and linearly related to the corresponding demographic data of districts ($r = 0.87$, $P < 0.05$).

The changes observed in the community structure along the urbanization gradient suggested different patterns for the attributes assessed (Fig. 5). The CI showed a peak at middle levels of urbanization (around 40% of PIA); this trend was statistically significant in all cases except in spring (Fig. 5a). TA and DC showed similar patterns (Fig. 5b and c), varying according to a third order polynomial trend statistically significant in the overall analysis for both variables, in autumn for TA, and in each sampling season for DC. Maximum values of TA and DC were observed at relative low levels

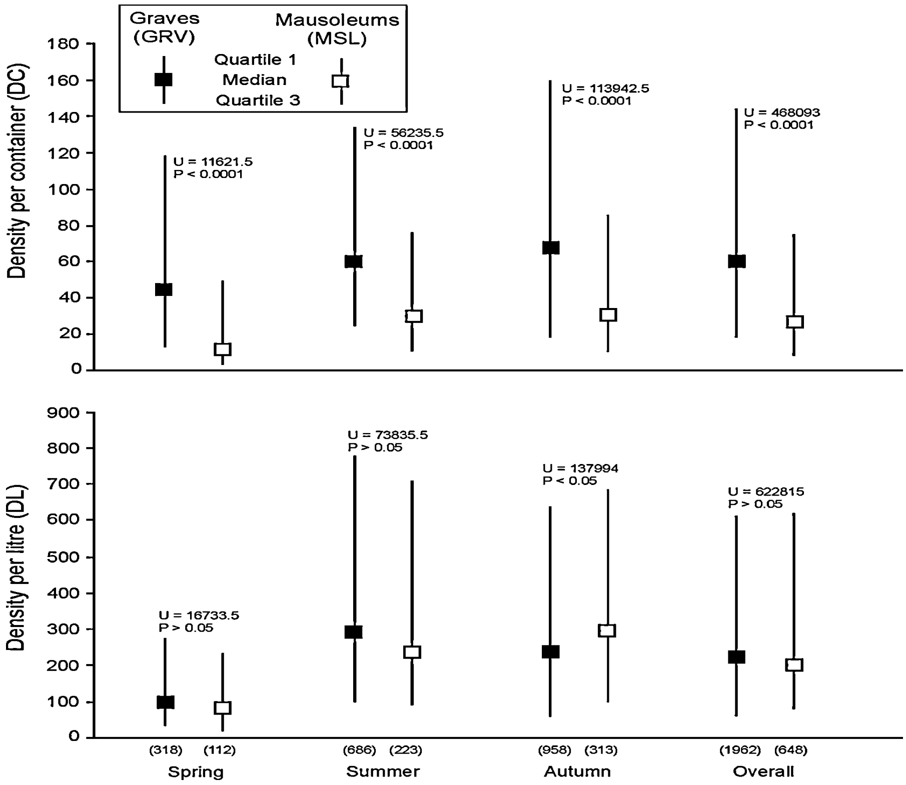


Fig. 3. Statistical comparison of the density of individuals per container (DC) and per liter (DL) between patch types according to the sampling season; sample size within brackets.

Table 3
Spearman's correlation coefficients (*r*) between estimators of abundance per each season; CI, container index; TA, total abundance and DC, density per infested container.

	Spring	Summer	Autumn
CI–TA	0.72^{**}	0.80^{***}	0.81^{***}
CI–DC	−0.15 ns	0.62^{*}	0.49 ns
TA–DC	0.02 ns	0.84^{***}	0.82^{***}

ns, not significant.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

of urbanization (around 20% of PIA). On the contrary, the variation of DL along the gradient did not show any evident pattern (Fig. 5d).

Regarding the species richness, the expected S showed no significant changes among cemeteries surrounded by different urbanization levels. The Sörensen index was mostly from high to very high and nearly constant (Fig. 5f), suggesting that the SC also was similar along the urbanization gradient. According to the Mantel test there was no spatial autocorrelation ($P > 0.05$ for all cases), meaning that the mentioned similarities in SC were unrelated to the distance among cemeteries.

Finally, overall CI, TA and DC resulted positively associated according to Spearman's correlation coefficients but with some differences depending on the season (Table 3). The relationship between CI and TA was the only sustained through the seasons.

4. Discussion

Our survey suggests that the responses of the studied Diptera community to the urbanization depend on the spatial scale. We found no evidence that the community structure differed at the local scale between neighboring patches of contrasting vegetation and building cover. Several studies focused on microenvironmental conditions within cemeteries have suggested that the vegetation acts a key factor in the presence and abundance of some Culicidae species because it provides shade and food for immatures and adults (Abe, McCall, Lenhart, Villegas, & Kroeger, 2005; Vezzani & Albicócco, 2009; Vezzani, Rubio, Velázquez, Schweigman, & Wiegand, 2005). So, although the life history of most of the species collected is unknown, it would be reasonable to expect similar effects of the vegetation on other fly species. As was previously stated, despite the huge difference in the environmental features between both patch types, the amount of occupied habitat, the richness, the abundance and the species composition did not change. In our study, patch types were defined based on our perception of contrasting environmental characteristics. However, human and fly perceptions of the environment do not always match (Haslett, 2001), and therefore, it cannot be disregarded that these patches are perceived as a continuous and homogeneous environment from the fly's eye view.

Regarding the landscape scale, our results indicated that the urbanization level around a cemetery affects some attributes of its Diptera community. The proportion of occupied habitat (CI) and the intensity of use of each container (DC) were greater at intermediate levels of urbanization. In accordance, the maximum numbers of individuals (TA) were also registered at intermediate levels and then decrease towards the more urbanized sites. Most of the studies dealing with urbanization effects on stream invertebrates have reported decreases in overall abundance as urbanization increases (Paul & Meyer, 2001). Comparative studies conducted in different cities using a common methodology and terrestrial invertebrates have found considerable variation in the response of the overall abundance to urbanization (e.g. Magura, Tóthmérész, Hornung, & Horváth, 2008; Niemelä et al., 2002). However, in agreement with our findings, cities from north temperate regions showed higher abundances in suburban sites (Niemelä et al., 2002). Noteworthy,

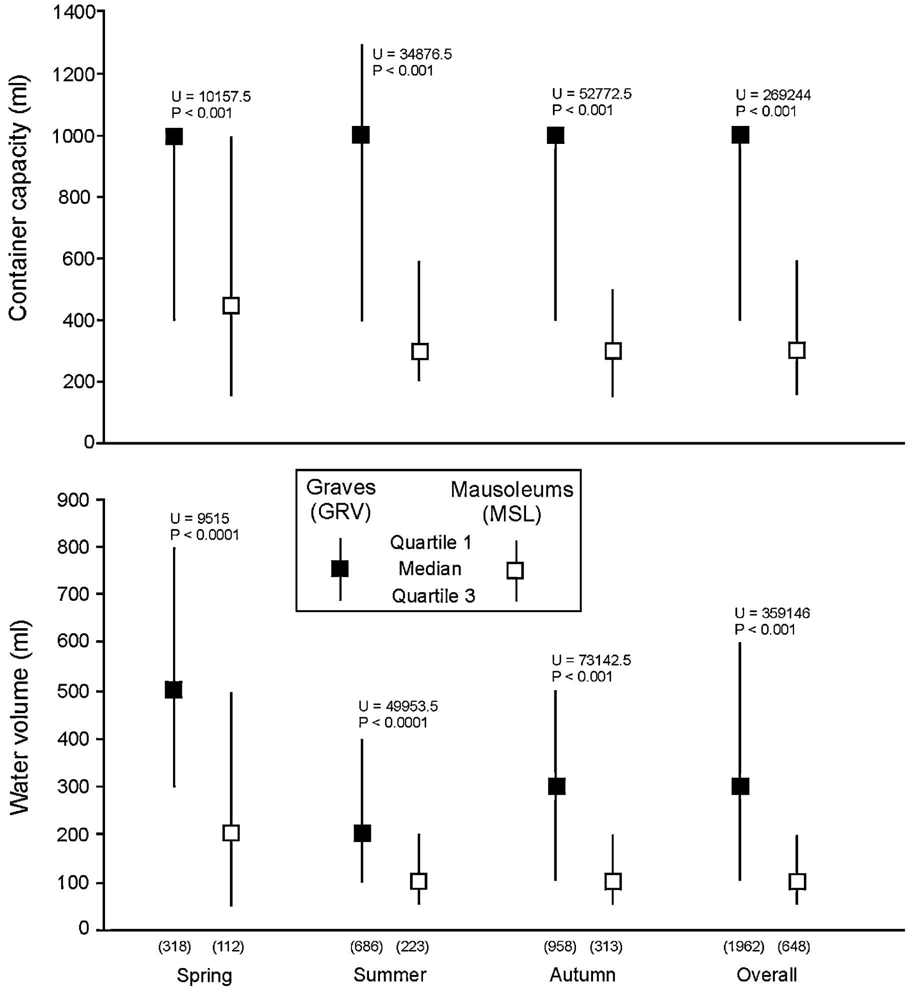


Fig. 4. Statistical comparison of the container capacity and the water volume between patch types according to the sampling season; sample size within brackets.

the analysis of the overall community abundance has been objected because it can mask particular trends of some species (Magura, Tóthmérész, & Molnár, 2004). Therefore, despite the high seasonal consistency observed in our research, specific abundance patterns of key species (e.g. beneficial or harmful insects for human activities) should be carefully considered because they could depart from the general abundance pattern.

The reasons of the greater abundance of container-breeding flies at intermediate levels of urbanization are possibly related to factors proved to be determinants of population abundance. Some of these factors, which are common for a wide range of fly species, could be postulated to understand the patterns of abundance for the entire community. In low-urbanized areas, higher predation levels and higher frequencies of extremely low minimum temperatures can maintain a low abundance of dipterans (McIntyre, Rango, Fagan, & Faeth, 2001). At the other extreme of the gradient, urban pollution combined with maximum temperatures and lowest humidity levels have been associated to decreases in insect abundance (Alstad, Edmundo, & Weinstein, 1982; Pimentel, 1994). In addition, suburban areas have a multiplicity of contrasting land uses (e.g. residential, industrial, agricultural), offering a great diversity of food, shelter and habitat sources. Another reasonable explanation of the observed pattern could be closely related to the larval habitat (i.e. the artificial container). Rural sites have a relatively low density of man-made containers in comparison with highly urbanized settings, and therefore, these environments might be less suitable for this particular fly community.

The diversity of the fly community (here assessed through the species richness by rarefaction curves) was quite similar along the urbanization gradient. Likewise, other fly community (a group of *Drosophila* species) showed no change in diversity along a native-urban gradient (Avondet, Blair, Berg, & Ebbert, 2003). Ground dwelling invertebrates have shown positive, negative or neutral responses of species richness to increasing urbanization (e.g. Alaruikka et al., 2002; McIntyre, 2000; McKinney, 2008), and thus, there is currently no consensus on general trends. Studies of urban effects on aquatic invertebrates of streams have reported decreases in diversity with increases of impervious surface cover (Paul & Meyer, 2001). On the other hand, McIntyre (2000) and Niemelä (1999) pointed the presence of urban-specialist or introduced species in urban settings as potential reasons of a higher richness in sites more urbanized. In our survey, the larval habitat is intrinsically favored by human activities, and thus, it is reasonable that the number of species using this water bodies does not decrease with the urbanization. In other words, the bulk of the fly species composing the community may be highly specialized in anthropic environments.

The species composition was from moderate to highly similar among cemeteries, and no relation was detected with the urbanization level in their surroundings. On the contrary, Avondet et al. (2003) reported that the composition of the *Drosophila* community gradually changed along the gradient considering several land uses in the sampling design (natural preserve, golf course, residential, etc.). Some studies have suggested that the land use could be

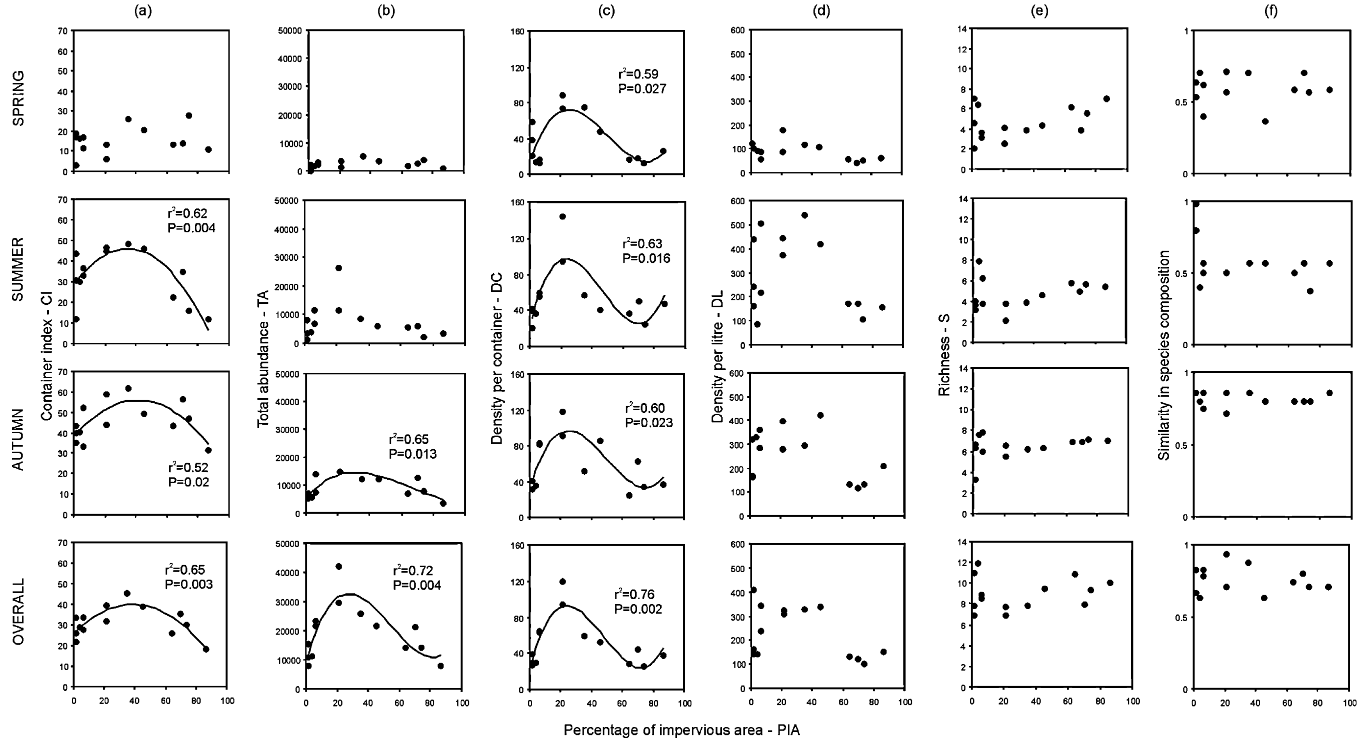


Fig. 5. Relationship between each response variable and the percentage of impervious area (PIA); (a) container index CI, (b) total abundance TA, (c) density per infested container DC, (d) density per liter DL, (e) species richness S, and (f) similarity in species composition SC.

a main factor driving insect community composition within the urban mosaic (McIntyre & Hostetler, 2001; McIntyre et al., 2001). In particular, dipteran assemblages and their relative abundances are considered sensitive to variations according to the human land use (Haslett, 2001). In this sense, it is possible that the land use 'cemetery' is determining the species composition of the fly community further than the intensity of the urbanization in its surroundings. This is probably the main bias of our study and further research on this particular community of urban flies in different land uses is needed.

Besides the main scope of this work, novel information about immature fly communities dwelling in containers from urban environments in temperate South America was provided. Out of the 126 Diptera families in Neotropical region, only 27 have aquatic species (Domínguez & Fernández, 2009). In this work, the first conducted for an exhaustive search of flies breeding in artificial containers in a complete temperate urban gradient, 11 families were represented among the 24 fly species recorded. In terms of species number, the most common families were Chironomidae and Muscidae, and including the abundance of individuals, Culicidae and Ceratopogonidae could be added to the list. In the other extreme, Ephydridae, Syrphidae, Tipulidae, Stratiomyidae, Sarcophagidae and Chaoboridae, could be considered as rare and mostly represented by one species. This pattern of species composition matches with those observed for dipteran communities in small natural containers like phytotelmata (reviewed by Greeney, 2001) and in discarded vehicle tires (reviewed by Yee, 2008), in which Culicidae, Ceratopogonidae, and Chironomidae were among the commonest families. Additionally, two recent works on dipteran communities in artificial containers other than tires, have reported consistent patterns. Hribar et al. (2004) found that Culicidae, Chironomidae, Ceratopogonidae, Psychodidae, and Phoridae occurred commonly in artificial and natural containers, sewage treatment plants, and storm drains in Florida (USA), and Leisnham et al. (2006) reported that about 60% of the larvae collected with experimental artificial containers in New Zealand belonged to Chironomidae. General findings strongly suggest that the extremely abundant man-made containers present in urbanized areas are being used as breeding habitat for a wide range of aquatic or semi-aquatic dipterans, echoing the composition of taxonomic groups observed in containers in the wild.

About one third of the water-filled flower vases were found with fly larvae. Not surprisingly, sites with extremely high density of containers, such as cemeteries, have been considered worldwide as high dipteran productivity areas (Ebeling, 1975). Seasonally, the amount of occupied habitat and the total abundance showed a marked tendency to rise from spring to autumn. However, the densities of individuals were slightly higher in summer. This might be explained by a reduction in the water volume in the containers as consequence of the water evaporation due to the high temperatures during that summer; daily maximum temperature ranges from 26 °C to 38 °C.

Finally, one of the main questions pending from our approach is whether the characterized community is representative of the container-breeding flies of urban land uses other than cemeteries. But indubitably, our survey revealed a relatively high number of fly species using flower vases from cemeteries as larval habitats. Thus, given that these habitats are target for mosquito control worldwide (Vezzani, 2007), the potential loss of Diptera biodiversity in urban settings should be considered in pest control management.

Acknowledgments

This study was partially supported by Consejo Nacional de Investigaciones Científicas y Técnicas (PIP 112-200801-00743). AR is fellow of CONICET, and MIB and DV are members of the Research Career of CONICET. We thank to cemeteries and municipalities authorities for fieldwork permissions. To Augusto Siri from the ILPLA for Chironomidae identification. To Andrea Albicócco, Natalia Aprigliano and Natalia Mesa Sierra for their help with the field work.

References

Abe, M., McCall, P. J., Lenhart, A., Villegas, E., & Kroeger, A. (2005). The Buen Pastor cemetery in Trujillo, Venezuela: Measuring dengue vector output from a public area. *Tropical Medicine and International Health*, *10*, 597–603.

Alaruikka, D., Kotze, D. J., Matveinen, K., & Niemelä, J. (2002). Carabid beetle and spider assemblages along a forested urban–rural gradient in southern Finland. *Journal of Insect Conservation*, *6*, 195–206.

Alstad, D. N., Edmundo, G. F., Jr., & Weinstein, L. H. (1982). Effects of air pollutants on insect populations. *Annual Review of Entomology*, *27*, 369–384.

Avondet, J. L., Blair, R. B., Berg, D. J., & Ebbert, M. A. (2003). Drosophila (Diptera: Drosophilidae) response to changes in ecological parameters across an urban gradient. *Environmental Entomology*, *32*, 347–358.

Buddle, C. M., Beguin, J., Bolduc, E., Mercado, A., Sackett, T. E., Selby, R. D., et al. (2005). The importance and use of taxon sampling curves for comparative biodiversity research with forest arthropod assemblages. *Canadian Entomologist*, *137*, 120–127.

Cavia, R., Cueto, G. R., & Suarez, O. V. (2009). Changes in rodent communities according to the landscape structure in an urban ecosystem. *Landscape and Urban Planning*, *90*, 11–19.

Cox, J., Grillet, M. E., Ramos, O. M., Amador, M., & Barrera, R. (2007). Habitat segregation of dengue vectors along an urban environmental gradient. *American Journal of Tropical Medicine and Hygiene*, *76*, 820–826.

Darsie, J. (1985). Mosquitoes of Argentina. Part I: Keys for Identification of adult females and fourth stage larvae in English and Spanish (Diptera, Culicidae). *Mosquito Systematics*, *17*, 153–253.

Domínguez, E., & Fernández, H. R. (2009). *Macroinvertebrados bentónicos sudamericanos: Sistemática y biología*. Tucumán: Fundación Miguel Lillo. [in Spanish].

Ebeling, W. (1975). Miscellaneous pests. In W. Ebeling (Ed.), *Urban entomology* (pp. 553–577). Berkeley, CA: Univ. California Press.

Epler, J. H. (2001). Identification manual for the larval Chironomidae (Diptera) of North and South Carolina. In *A guide to the taxonomy of the midges of the Southeastern United States, including Florida*. North Carolina Department of Environment and Natural Resources: Raleigh, NC.

Faggi, A. M., Krellenberg, K., Castro, R., Arriaga, M., & Endlicher, W. (2008). Biodiversity in the Argentinean rolling pampa ecoregion: Changes caused by agriculture and urbanisation. In J. M. Marzluff, E. Shulenberger, W. Endlicher, M. Alberti, G. Bradley, C. Ryan, U. Simon, & C. Zumbrunnen (Eds.), *Urban ecology. An international perspective on the interaction between humans and nature* (pp. 377–389). New York, NY: Springer.

Fleiss, J. L., Levin, B., & Paik, M. C. (2003). *Statistical methods for rates and proportions* (3rd ed.). New Jersey, NJ: Wiley & Sons.

Garaffa, P. I., Filloy, J., & Bellocq, M. I. (2009). Bird community responses along urban–rural gradients: Does the size of the urbanized area matter? *Landscape and Urban Planning*, *90*, 33–41.

Greeney, H. F. (2001). The insects of plant held waters: A review and bibliography. *Journal of Tropical Ecology*, *17*, 241–260.

Hansen, A. J., Knight, R. L., Marlzuff, J. M., Powell, S., Brown, K., Gude, P. H., et al. (2005). Effects of exurban development on biodiversity: Patterns, mechanisms and research needs. *Ecological Applications*, *15*, 1893–1905.

Haslett, J. R. (2001). Biodiversity and conservation of Diptera in heterogeneous land mosaics: A fly's eye view. *Journal of Insect Conservation*, *5*, 71–75.

Hribar, L. J., Vlach, J. J., DeMay, D. J., James, S. S., Fahey, J. S., & Fussell, E. M. (2004). Mosquito larvae (Culicidae) and other Diptera associated with containers, storm drains, and sewage treatment plants in the Florida Keys, Monroe County, Florida. *Florida Entomologist*, *87*, 199–203.

INDEC. (2010). *Censo nacional de población, hogares y viviendas 2010: Total del país, resultados provisionales. Primera edición*. Buenos Aires, BA: Instituto Nacional de Estadística y Censos. [in Spanish].

Krebs, C. (1989). *Ecological methodology*. New York, NY: Harper & Raw.

Legendre, P., & Legendre, L. (1998). *Numerical ecology*. Amsterdam: Elsevier.

Leisnham, P. T., Lester, P. J., Slaney, D. P., & Weinstein, P. (2006). Relationships between mosquito densities in artificial container habitats, land use and temperature in the Kapiti-Horowhenua region New Zealand. *New Zealand Journal of Marine Freshwater Research*, *40*, 285–297.

Magrin, G., Travasso, M. I., Díaz, R., & Rodríguez, R. (1997). Vulnerability of the agricultural systems of Argentina to climate change. *Climate Research*, *9*, 31–36.

Magura, T., Tóthmérész, B., Hornung, E., & Horváth, R. (2008). Urbanization and ground-dwelling invertebrates. In L. N. Wagner (Ed.), *Urbanization: 21st century issues and challenges* (pp. 213–225). New York, NY: Nova Science Publishers Inc.

Magura, T., Tóthmérész, B., & Molnár, T. (2004). Changes in carabid beetle assemblages along an urbanisation gradient in the city of Debrecen, Hungary. *Landscape Ecology*, *19*, 747–759.

Magurran, A. E. (2004). *Measuring biological diversity*. Oxford: Blackwell.

Matteucci, S. D., & Morello, J. (2009). Environmental consequences of exurban expansion in an agricultural area: the case of the Argentinian Pampas ecoregion. *Urban Ecosystems*, *12*, 287–310.

McAlpine, J. F., Peterson, B. V., Shewell, G. E., Teskey, H. J., Vockeroth, J. R., & Wood, D. M. (1981). *Manual of Nearctic Diptera* Quebec: Research Branch Agriculture Canada.

McIntyre, N. E. (2000). Ecology of urban arthropods: A review and call to action. *Annals of the Entomological Society of America*, *93*, 825–835.

McIntyre, N. E., & Hostetler, M. E. (2001). Effects of urban land use on pollinator (Hymenoptera: Apoidea) communities in a desert metropolis. *Basic and Applied Ecology*, *3*, 209–218.

McIntyre, N. E., Knowles-Yánez, K., & Hope, D. (2000). Urban ecology as an interdisciplinary field: Differences in the use of urban between the social and natural sciences. *Urban Ecosystem*, *4*, 5–24.

McIntyre, N. E., & Rango, J. (2009). Arthropods in urban ecosystems: Community patterns as functions of anthropoenic land use. In M. J. McDonnell, A. K. Hahs, & J. H. Breuste (Eds.), *Ecology of cities and towns: A comparative approach* (pp. 233–242). New York, NY: Cambridge University Press.

McIntyre, N. E., Rango, J., Fagan, W. F., & Faeth, S. H. (2001). Ground arthropod community structure in a heterogeneous urban environment. *Landscape and Urban Planning*, *52*, 257–274.

McKinney, M. L. (2002). Urbanization, biodiversity and conservation. *Bioscience*, *52*, 883–890.

McKinney, M. L. (2008). Effects of urbanization on species richness: A review of plants and animals. *Urban Ecosystems*, *11*, 161–176.

Niemelä, J. (1999). Ecology and urban planning. *Biodiversity and Conservation*, *8*, 119–131.

Niemelä, J., Kotze, D. J., Venn, S., Penev, L., Stoyanov, I., Spence, J., et al. (2002). Carabid beetle assemblages (Coleoptera, Carabidae) across urban–rural gradients: An international comparison. *Landscape Ecology*, *17*, 387–401.

Pauchard, A., Aguayo, M., Peña, E., & Urrutia, R. (2006). Multiple effects of urbanization on the biodiversity of developing counties: The case of a fast-growing metropolitan area (Concepción, Chile). *Biological Conservation*, *127*, 272–281.

Paul, M. J., & Meyer, J. L. (2001). Streams in the urban landscape. *Annual Review of Ecology and Systematics*, *32*, 333–365.

Pickett, S. T. A., Cadenasso, M. L., Grove, J. M., Nikon, C. H., Pouyat, E. V., Zipperer, W. C., et al. (2001). Urban ecological systems: Linking terrestrial ecological, physical, and socioeconomic components of metropolitan areas. *Annual Review of Ecology and Systematics*, *32*, 127–157.

Pimentel, D. (1994). Insect population responses to environmental stress and pollutants. *Environmental Reviews*, *2*, 1–15.

Rossi, G. C., Mariluis, J. C., Schnack, J. A., & Spinelli, G. R. (2002). *Dípteros vectores (Culicidae y Calliphoridae) de la Provincia de Buenos Aires*. Buenos Aires, BA: Secretaría de Política Ambiental y Universidad de la Plata. [in Spanish].

Service, M. W. (1995). Mosquitoes (Culicidae). In R. P. Lane, & R. W. Crosskey (Eds.), *Medical insects and arachnids* (pp. 120–240). London: Chapman & Hall.

Siegel, S., & Castellan, N. J. (1995). *Estadística no paramétrica: aplicada a las ciencias de la conducta*. México, DF: Trillas. [in Spanish].

Smith, R. M., Gaston, K. J., Warren, P. H., & Thompson, K. (2006). Urban domestic gardens (VIII): Environmental correlates of invertebrate abundance. *Biodiversity and Conservation*, *15*, 2515–2545.

UNDP. (2009). *Annual report of United Nations development programme*. New York, NY: United Nations.

Vezzani, D. (2007). Artificial container-breeding mosquitoes and cemeteries: A perfect match. *Tropical Medicine and International Health*, *12*, 199–313.

Vezzani, D., & Albicócco, A. P. (2009). The effect of shade on the container index and pupal productivity of the mosquitoes *Aedes aegypti* and *Culex pipiens* breeding in artificial-containers. *Medical and Veterinary Entomology*, *23*, 78–84.

Vezzani, D., Rubio, A., Velázquez, S. M., Schweigman, N., & Wiegand, T. (2005). Detailed assessment of microhabitat suitability for *Aedes aegypti* (Diptera: Culicidae) in Buenos Aires, Argentina. *Acta Tropica*, *95*, 123–131.

Wiederholm, T. (1983). Chironomidae of the Holarctic region. Keys and diagnoses. Part 1: Larvae. *Entomologica Scandinavica*, *19*, 1–457.

Yee, D. A. (2008). Tires as habitats for mosquitoes: A review of studies within the eastern United States. *Journal of Medical Entomology*, *45*, 581–593.

Zar, J. H. (1999). *Biostatistical analysis*. New Jersey, NJ: Prentice Hall.