Urban rain pools: seasonal dynamics and entomofauna in a park of Buenos Aires

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Abstract

We describe the seasonal variations of the insect community of the rain pools in a park of Buenos Aires during a 1-year period, based on a weekly sampling programme. We also analyse the relationships between the observed biotic patterns and some physical and meteorological variables. Four periods, fairly coincident with the seasons of the year, were graphically identified as functions of temperature, rainfall, flooded area, number of rain pools, depth and taxonomic richness. A total of 45 insect taxa was identified: 18 Coleoptera, 15 Diptera, 9 Heteroptera, 1 Ephemeroptera and 2 Odonata. Culicidae represented 76% of the pooled abundance of insects, probably related to their rapid development before the pools dry up. Taxonomic richness was maximum at the end of the summer (32), in coincidence with maximum rainfalls and temperatures. Inversely, the minimum richness (2) was recorded during the spring drought. Richness was positively correlated to the flooded area and to the number of pools on each sampling date. The species recorded throughout the study period were: *Aedes albifasciatus*, *Culex eduardoi*, *Culex pipiens*, *Liodessus* sp., *Rhantus signatus signatus*, *Tropisternus setiger*, *Tropisternus lateralis limbatus* and *Sigara platensis*. Some of the species recorded are considered pioneer in temporary habitats. Both coleopterans and heteropterans are likely to persist in the park through repeated colonisation from more permanent habitats. Habitat duration and flooded area were positively correlated to richness in each one of the rain pools.

Introduction

Rain pools are small temporary water bodies of variable duration formed where rain collects in little depressions (Williams, 1992). These habitats present a recurrent dry phase, thus undergoing important variations in their physical and chemical conditions (Williams, 1996).

The most important abiotic factors affecting the rain pool fauna are permanence and water temperature (Nilsson & Svensson, 1994). The aquatic invertebrates living in these habitats have developed different adaptive strategies to resist important fluctuations in the environmental conditions, and at the same time exploit the abundant resources offered by the pools. These strategies include physiological tolerance, migration and changes in the life history (Williams, 1996). The adaptation of the fauna to this particular type of environment is conditioned by the ability of these organisms to complete their development cycles before the pool dries up (Nilsson & Svensson, 1994).

Two main assemblages of insects with different life cycle strategies can be distinguished among the inhabitants of temporary pools. A rapid development of preimaginal stages and the emergence of adults prior to the dry phase characterize the first one. The adults of the second group disperse either opportunistically or seasonally from more permanent water bodies to temporary habitats where oviposition and larval development take place (Fernando & Galbraith, 1973; Williams, 1996). The first strategy is shown in species whose immature stages are aquatic (e.g. culicids

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and chironomids). The second one encompasses some aquatic hemipterans and coleopterans that spend their whole life cycles either within or close to water bodies (Fernando & Galbraith, 1973).

Several culicid species are typical inhabitants of temporary waters (Nilsson & Svensson, 1994; Ludueña Almeida & Gorla, 1995; Almirón & Brewer, 1996; Schneider & Frost, 1996; Williams, 1996), and some of them have sanitary importance owing to their potential as vectors of human and animal diseases (Service, 1993).

Except for a few works on Culicidae (Del Ponte & Blaksley, 1947; Manso Soto & Martínez, 1948, 1949), the study of the fauna of urban temporary pools of the city of Buenos Aires has been largely neglected. On the other hand, the physical dynamics of these rain pools has never been investigated. The present contribution is aimed at describing the seasonal variations of the insect community of the rain pools in a park of Buenos Aires during a 1-year period (1998–1999). We also analyse the relationships between the observed biological patterns and some relevant physical and meteorological variables.

Study area

Surveys were carried out in a sector (approximately 8 ha) of Brigadier General Cornelio Saavedra Park. This 9.4-ha parkland is located at low altitude (6–10 m a.s.l.) in the northern zone of the city of Buenos Aires. It lies over the piping of Medrano Spring, which runs in a west-east direction along the longest axis of the park. The vegetation of this park is mainly grass subjected to periodical cut, and trees that are distributed in the whole area producing a differential shade of the pools. The park was occasionally sprayed with deltamethrin to control adult culicids.

The irregular relief of the land is favourable to the formation of a great number of ephemeral pools of variable size (0.2–600 m^2) after rainfall events. The permanence of these water bodies ranges from 1 week to several months, depending on meteorological conditions. Since this recreational space is located in a densely populated urban area, it is regularly visited by a great number of people and dogs that produce an intense perturbation of the pools. Halfway through the study period, the city government started improvement works in the park, involving the filling of some pools. However, in May 1999 filled pools attained only 14% of the total number of environments surveyed.

Materials and methods

All the pools present in the study area were evaluated weekly between June 1998 and May 1999. Weekly median depth and total flooded area were calculated from the maximum depth and surface area of each pool measured on every survey. Weekly mean temperature and weekly-accumulated rainfall were calculated from the daily records provided by the National Meteorological Service.

Faunal samples were collected with a hand net (350 μm mesh size) dragged along the bottom, on a single haul that covered the longest axis of each pool. Therefore, the sample was considered proportional to the length of the pool. An 80-ml dipper was used as the sample unit in the shallowest pools. The number of sampling units collected was proportional to the surface area of each water body, ranging from 5 to 60 dippers. These sampling methods are probably most effective at collecting open water fauna, whereas some benthic organisms may have been underestimated. The samples were fixed *in situ* in 5% formaldehyde and stored in 80% ethanol.

Adults and immature stages of Culicidae, Coleoptera and Heteroptera were identified to the specific or generic level using the appropriate systematic keys and specialised literature on the local fauna (Merrit & Cummins, 1984; Darsie, 1985; Angrisano & Trémouilles, 1995; Bachmann & Mazzucconi, 1995; Trémouilles et al., 1995 Almirón & Harbach, 1996; Bachmann & Angrisano, 1998). Those immature specimens of Coleoptera and Heteroptera that were not described in the literature, were identified to the generic level and assigned to a particular species provided that a single species of a genus were recorded throughout the study period. Odonata, Ephemeroptera and non-Culicidae Diptera were identified to suborders and families, respectively, since we considered that a higher taxonomic resolution would not change significantly the results of the study.

The monthly numbers of individuals of the different taxa were used to compare the proportions of the different taxonomic groups and trophic categories (detritivores, predators and herbivores), following Merrit & Cummins (1984). Variations in the monthly taxonomic richness of adults and immature stages were also analysed.

In order to evaluate the relationship between richness and the amount of water in the park, the total richness on each sampling date was correlated to the flooded area and number of pools, both for the whole

study period and seasonally. Since our data did not meet the requirements to apply a parametric test, we used the Spearman rank correlation (Zar, 1984).

In order to analyse the distribution pattern of taxonomic richness, we considered the accumulated number of taxa throughout the year in each pool. The variance-mean relation was calculated and the adjustment of the frequency distribution to a negative binomial model was also tested (Elliott, 1977). Spearman rank correlations were used to evaluate the relationship among the annual richness of each pool and its maximum and mean duration, and its maximum size.

Results

Meteorological variables and rain pool dynamics

Four periods, fairly coincident with the seasons of the year, were graphically identified by considering the dynamics of the water bodies together with some relevant meteorological parameters (Figs 1A,B,C). In winter (between June and August), at mean temperatures of 11–15 °C and under a monthly-accumulated rainfall mean of 48 mm (Fig. 1A), both the number of rain pools (Fig. 1B) and the flooded area (Fig. 1C) attained their maximum values. The water bodies present during the whole winter period, varied from 30 to 60 mm in median depth. Although winter and spring accumulated rainfall records were similar, the spring was characterised by a period of drought and also by the brief duration of the rain pools. In the spring, the median depth of the pools never surpassed 40 mm, and the park was totally dry on several occasions. In the summer, the monthly accumulated rainfall mean exceeded 150 mm, whereas monthly mean temperatures varied between 20 and 27 °C. The maximum fluctuations in pool median depth were observed during this season (0–80 mm). The fall was a relatively dry period (Fig. 1C), with a monthly-accumulated rainfall mean of 80 mm.

Seasonal presence of insects

Approximately 8400 specimens belonging to 45 insect taxa from 5 orders were collected. Table 1 reflects the variations in the relative abundance of each taxon throughout the year. Microcrustaceans (cladocerans, cyclopoid copepods and ostracods), Nematoda, Oligochaeta, Hydrachnida and Collembola, were also collected but are not included in the present analysis. The most diverse insect orders were Coleoptera (18
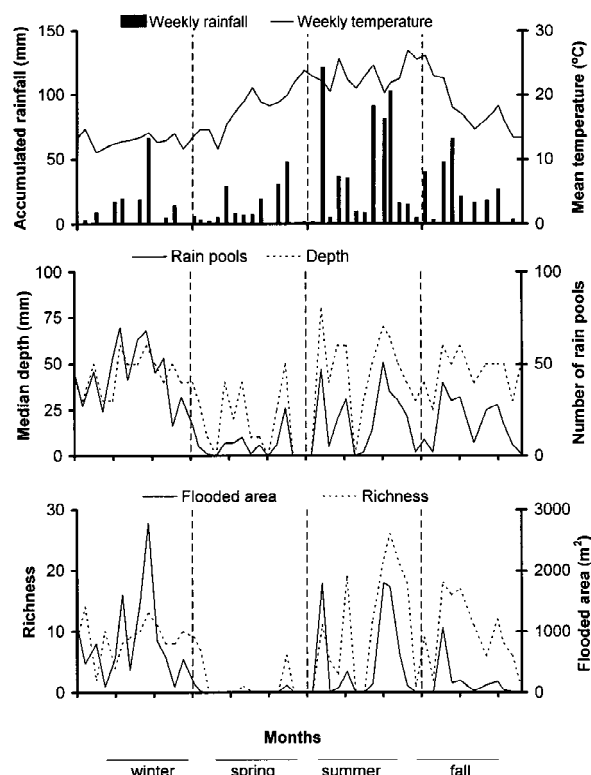

Figure 1. (A) Weekly variation of accumulated rainfall and mean temperature; (B) weekly variation of rain pool median depth and rain pool number; and (C) weekly variation of taxonomic richness and flooded area in Saavedra Park (Buenos Aires, Argentina), during the study year.

taxa belonging to 13 genera and 3 families), Diptera (15 taxa belonging to 8 families) and Heteroptera (9 taxa belonging to 8 families) (Table 1).

Dipterans were the most abundant organisms year round, except for the November–January period, when Coleoptera accounted for the greatest proportion of the entomofauna, in coincidence with the lowest total number of specimens (Fig. 2). Culicidae outnumbered all the other taxa, representing 76% of the insects collected throughout the study period.

Some coleopterans (*Rhantus signatus signatus* Fabricius 1775, *Liodessus* spp., and *Tropisternus* spp.), heteropterans (*Sigara platensis* (Bachmann, 1962)), ephemeropterans (Baetidae), and dipterans (Chironomidae, *Culex eduardoi* Casal & Garcia, 1968, *Culex pipiens* Linnaeus, 1758 and *Aedes albifasciatus* (Macquart, 1838)) were present during the whole year. The latter mosquito species was also the dominant organism in all seasons (Table 1).

Table 1. Monthly variation in the relative abundance of the different insect taxa recorded in Saavedra Park (Buenos Aires, Argentina), during the study year. L: larvae, L1: larval instar 1, L2: larval instar 2, and pu: pupa

Taxa	J	J	A	S	O	N	D	J	F	M	A	M
Coleoptera												
Dytiscidae												
Liodessus sp.		38	54	11		33	26	63	148	18	58	14
Liodessus sp. (L)			2						130	1	50	4
Desmopachria (Nectoserrula) sp.			1	1		1	1	7	6	3		
Desmopachria (Desmopachria) sp.									1			
Thermonectus succinctus (Aubé, 1838)	1	1					2		1	1		
Thermonectus succinctus (Aubé, 1838) (L)							1		7		1	
Laccophilus sp.							2	1	1			
Rhantus signatus signatus (Fab., 1775)		1				1	3		2	1	2	
Rhantus signatus signatus (Fab., 1775) (L)	7	2	40	3					54		9	
Laccornellus tristis (Brullé, 1837)											2	
Hydrophilidae												
Tropisternus setiger (Germar, 1824)	2						14	11	21		2	3
Tropisternus lateralis limbatus (Brullé, 1837)						6	18	1	8	1		
Tropisternus ignoratus Knisch, 1921							2			1		
Tropisternus dilatatus Bruch, 1915							1					
Tropisternus spp. (L)	1	2	1	1			6	2	148		6	
Paracymus sp.				1		1	1	2	1	1	1	
Paracymus sp. (L)												1
Enochrus circumcinctus (Bruch, 1915)						2	7		1			
Enochrus obsoletus (Bruch, 1915)						1			1	1		
Enochrus sp. (L)												
Berosus sp.		1				1	3	1		1		
Derallus paranensis Oliva, 1989							2					
Noteridae												
Suphis sp.								1		1	1	
Suphisellus sp.							1	1				
Heteroptera												
Corixidae												
Sigara platensis Bachmann, 1962	7	39	36	1		2	14	12	2	3	5	
Sigara platensis Bachmann, 1962 (L)	3		4	27				32		3		
Notonectidae												
Notonecta sellata Fieber, 1851	2	5				1	3	1	2	4		
Notonecta sellata Fieber, 1851 (L)								10				
Buenoa fuscipennis (Berg, 1879)			1			2	3		1	1	1	
Belostomatidae												
Belostoma elegans (Mayr, 1871)			1				1		1	1		
Belostoma elegans (Mayr, 1871) (L)								54	1			
Pleidae												
Neoplea maculosa (Berg, 1879)								4	12			
Neoplea maculosa (Berg, 1879) (L)									1			
Ranatridae												
Ranatra sjostedti Montandon, 1911							4	1				
Veliidae												
Microvelia sp.		12	1				2	18	2			
Microvelia sp. (L)								1				

Table 1. Continued

Taxa	J	J	A	S	O	N	D	J	F	M	A	M
Hydrometridae												
Hydrometra argentina Berg 1879							2					
Hebridae												
Lipogomphus lacuniferus Berg, 1879								13	1			
Lipogomphus lacuniferus Berg, 1879 (L)								3				
Diptera												
Culicidae												
Aedes albifasciatus (Macquart, 1836) (L, pu)	991	472	977	140	2	2	50	68	160	968	81	223
Aedes crinifer (Theobald, 1903) (L)	1	2										
Culex sp. (L1, L2, pu)	34	102	82	6			2	515	5	188	85	
Culex eduardoi Casal & García, 1968 (L)	39	57	172	8					60		32	30
Culex pipiens Linnaeus, 1758 (L)	4	3					1	716	2	4	1	
Culex maxi Dyar, 1928 (L)	4								8	2	34	9
Culex tatoi Casal & García, 1971 (L)								3		1		
Anopheles sp. (L)	2									5		
Psorophora sp. (L)									7	1		
Chironomidae (L, pu)	11	17	61	83	1		1		156	4	31	10
Psychodidae (L, pu)		1	1									
Tipulidae (L)			1	1							1	
Muscidae (L)								1		9	4	
Ephydridae (L)		1							7	1	5	2
Ceratopogonidae (L)								3	2	1	1	
Stratiomyidae (L)								7	5			
Ephemeroptera												
Baetidae (L)	23	2	2			1		109		11	4	
Odonata												
Anisoptera (L)								8	1	1		
Zygoptera (L)								17				

Among coleopterans, the larger number of larvae corresponded to *Liodessus* spp., *Thermonectus succinctus* (Aubé, 1838), *R. signatus signatus* and *Tropisternus* spp., whereas among heteropterans most nymphs belonged to *S. platensis* and *Belostoma elegans* (Mayr, 1871). The immature stages of some taxa were recorded only occasionally (e.g. *Notonecta sellata* Fieber, 1851, *Enochrus* spp, *Paracymus* sp., *Neoplea maculosa* (Berg, 1879), *Microvelia* sp., and *Lipogomphus lacuniferus* Berg, 1879). The larvae of the remaining taxa were never detected. Some species were detected on a single occasion: *Desmopachria (D.)* sp., *Laccornellus tristis* (Brullé, 1837), *Tropisternus dilatatus* Bruch, 1915, *Derallus paranensis* Oliva, 1981 and *Hydrometra argentina* Berg, 1879.

Considering trophic categories, detritivores, mainly represented by culicids, were almost always dominant, whereas predators (mostly coleopterans and heteropterans) were most abundant in December and January. On the other hand, herbivores were scarce during the whole study period.

Taxonomic richness was maximum (32) in February and minimum (2) during the October drought (Fig. 1C). In spite of seasonal differences in the relationship between richness and water quantity, positive correlations between richness and flooded area, and richness and the number of rain pools were verified during the whole year (rs=0.74, *p*<0.001 and rs=0.68, *p*<0.001, respectively).
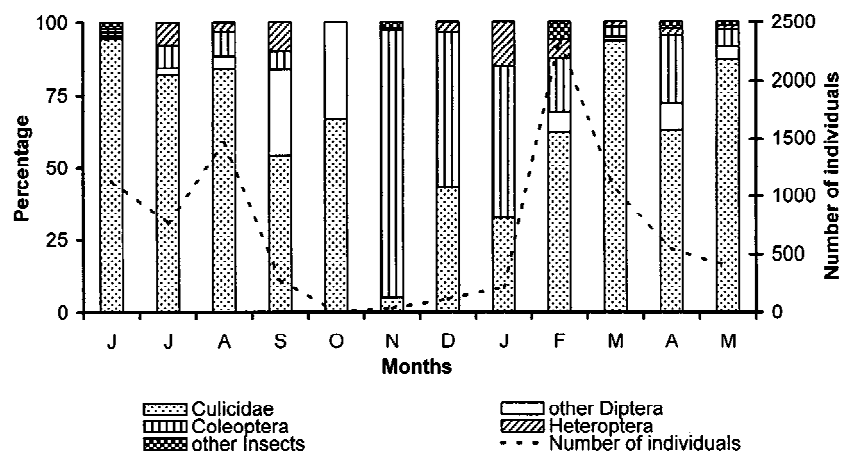
Figure 2. Monthly mean percentages of the main insect taxa and total number of individuals present in the rain pools of Saavedra Park (Buenos Aires, Argentina), during the study year.
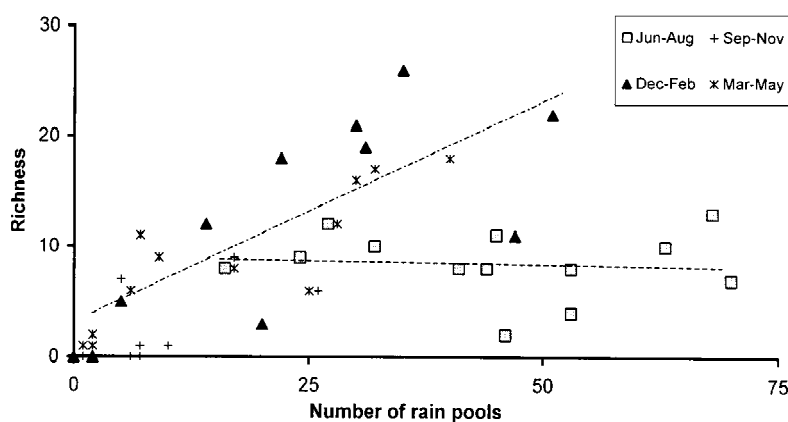

Figure 3. Seasonal trends of variation of taxonomic richness as a function of the number of rain pools in Saavedra Park (Buenos Aires, Argentina), during the study year.

The relationship between taxonomic richness and the number of rain pools varied seasonally (Fig. 3). During the coldest period (June–August), this correlation was not significant. Contrasting with this pattern, during the spring and the summer it showed a positive significant correlation (rs=0.67, $p<0.05$ and rs=0.67, $p<0.05$, respectively), whereas during the fall it was highly significant (rs=0.91, $p<0.001$).

Figure 4 shows the variation in the richness of adults and immature stages along the study period. The highest richness of adults was recorded during the warmer months (Fig. 4A). Adults, including coleopterans and heteropterans, attained their highest richness between December and April, with a peak value of 20 taxa in January. The highest richness of immature forms was recorded between February and April (Fig. 4B). Immature coleopterans, heteropterans,

dipterans and ephemeropterans were dominant at the beginning of this season, whereas dipterans were the best-represented taxa from March through April. In the summer, a time lag of approximately one month was observed between the appearance of the first adult specimens (January) and the immature stages (February). Therefore, summer maxima of adult and immature richness were out of phase.

The distribution of taxonomic richness in the pools showed a grouped pattern (Fig. 5), with a variance-mean relationship significantly higher than unit and a good adjustment to a negative binomial model ($p<0.05$). The annual richness in each pool was positively correlated to its maximum and mean duration, and to its maximum flooded area (rs=0.74, $p<0.001$; rs=0.64, $p<0.001$; and rs=0.57, $p<0.001$, respectively). As a general rule, all the taxa present in the
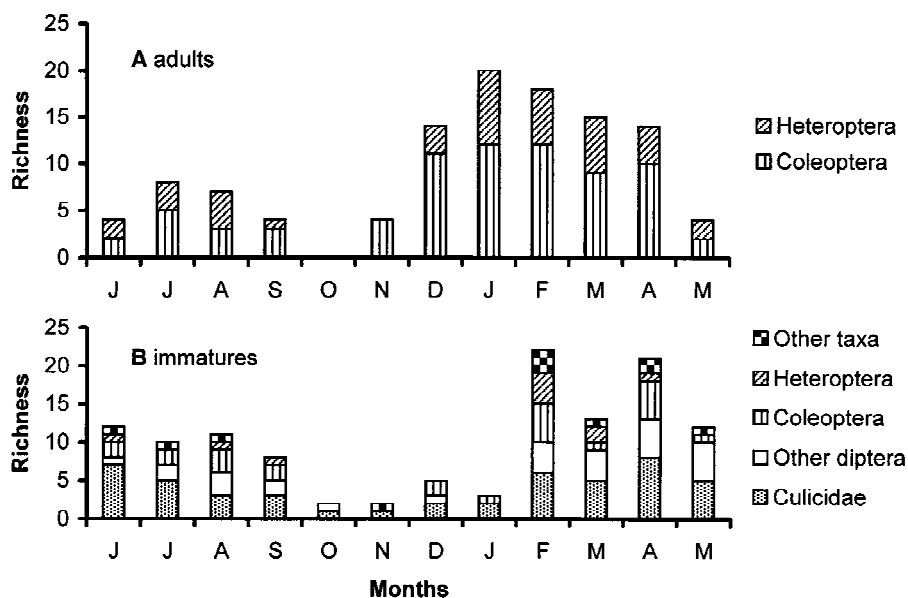
Figure 4. Taxonomic richness of adults (A) and immature stages (B) discriminated by major taxa, in all the Saavedra Park pools (Buenos Aires, Argentina), during the study year.
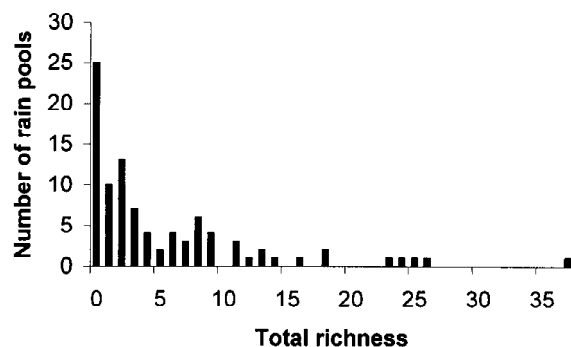

Figure 5. Frequency distribution of the different richness categories in all the Saavedra Park pools (Buenos Aires, Argentina).

poorest pools were also recorded in the richest pools, with the exception of *Laccornellus tristis*, which was exclusively found in two pools of low richness.

Five percent of the pools had the highest richness (over 50% of the recorded taxa), 7% had intermediate values (between 25 and 50% of the taxa) and 87% accounted for the lowest richness (less than 25% of the recorded taxa) (Fig. 5). Within certain limits, the pools maintained stable levels of richness throughout the year.

Discussion

Both rainfall and temperature regimes influence the number and duration of temporary pools. However, temperature seems to be the main factor involved in determining the extension of the flooded area and the permanence of the water bodies in Saavedra Park. Periods with similar accumulated rainfall records (winter and spring) but with different temperatures showed opposite values of flooded area and number of rain pools. A rapid absorption of water by the dry ground together with an accelerated evaporation would be responsible for the lower number of pools and the rapid changes in depth observed during the summer.

The relatively low median depth corresponding to the winter derives from the inclusion of a high number of very shallow pools in the calculation of this parameter. Under low temperatures and poor insolation, the drying time of these ephemeral pools was slow, generally more than 1 week. On the contrary, during the warmer months, the most ephemeral and shallow rain pools did not form at all.

The rapid development of the preimaginal stages of dipterans, particularly culicids and chironomids, allows them to complete the aquatic phase of their life cycles before the water bodies dry up (Fernando & Galbraith, 1973) in an predator-free environment (Wellborn et al., 1996). *Aedes* species are typically present in large numbers in ponds of short duration (Schneider & Frost, 1996), where they are considered to be an important part of the available food resources,

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especially for beetle larvae (Nilsson & Svensson, 1994).

A. albifasciatus, the most abundant species in the studied pools, is known to eventually produce explosive emergences of adults, both in rural and urban areas (Del Ponte & Blaksley, 1947; Ludueña Almeida & Gorla, 1995). Chironomids and some culicids of the genus *Aedes* are known to resist drought, either as larvae or eggs (Wiggins et al., 1980; Williams, 1996; Bazzanti et al., 1997).

Some of the species recorded in the pools (e.g. *N. maculosa*, *N. sellata*, *Buenoa fuscipennis* (Berg, 1879) and *S. platensis*) are considered pioneer (Bachmann & Angrisano, 1998). On the other hand, *A. albifasciatus*, like other floodwater mosquitoes, typically breeds in temporary habitats (Ludueña Almeida & Gorla, 1995). Studies carried out in temporary environments in England, Italy, North America, Australia, and New Zealand (Stout, 1964; Wiggins et al., 1980; Nilsson & Svensson, 1994; Schneider & Frost, 1996; Bazzanti et al., 1997; Williams, 1997), mention several species of *Rhantus*, *Laccophilus*, *Berosus*, *Sigara*, *Notonecta*, *Microvelia* and *Aedes* as typical of this kind of habitat.

Among the insects found in the rain pools of Saavedra Park, the taxa that may be considered as characteristic of this community type were those present in all seasons: *R. signatus signatus*, *Liodessus* spp., *Tropisternus* spp., *S. platensis*, *C. eduardoi*, *C. pipiens* and *A. albifasciatus*, as well as Baetidae and Chironomidae. Furthermore, these taxa showed higher abundances and were present in greater number of pools. The distinction between 'core' and 'satellite' species is useful to identify those species that are potentially most interactive (Nilsson, 1986). Defining as 'core' the reproducing species of higher abundance, the above mentioned taxa may be considered as the core species of the park. This topic deserves however further research to be tested.

Contrasting with the high quantities of culicids observed as a whole, the number of immature coleopterans and heteropterans was relatively low. Most of the rain pools of Saavedra Park may be unsuitable as breeding sites for these predatory taxa. This is probably linked to the short hydroperiod of these water bodies, which in many cases, may preclude the completion of the larval development before the pools enter the dry phase. In fact, predatory species are often totally absent from the most ephemeral habitats (Wellborn et al., 1996). Other studies have shown that the dominant insects in seasonal environments (coleopterans, corixids and some dipterans) persisted through repeated colonisation from more permanent habitats, rather than by physiological tolerance (Williams, 1997).

The increase in the richness of adult Coleoptera and Heteroptera starting from December may result from their active dispersal by flight from more permanent habitats at the beginning of the summer. Most of the taxa in these orders belong to the 'group 4' of Wiggins et al. (1980), that are characterised by colonising recently filled temporary habitats in the spring and also by their considerable dispersal capacity. In contrast to the adults, the increase in the richness of immature forms starting in February was coincidence with the heaviest rainfalls and the longest permanence of the water during the summer.

Most of the richness was usually concentrated in a few water bodies of greater duration and size. The positive relationships between the number of taxa and the flooded area, also observed by other authors (Bazzanti et al., 1996), and between the number of taxa and mean and maximum duration of the pool (this study), suggest that both greater area and longer permanence would originate a higher availability and diversity of microhabitats in a pool. Coleoptera and Heteroptera in particular seem to colonise rain pools as a function of their surface areas (Bazzanti et al., 1996). This would indicate that temporal variations in the richness might be linked to changes in the conditions of the richer pools more than to the actual amount of water accumulated in the park.

The present research is a first contribution to the knowledge of the physical and biological dynamics of urban rain pools of Buenos Aires City. Our data represent highly fragmented and disturbed habitats of an urban environment from a biogeographic region were few similar studies have been done. Although biotic interactions among the different taxa have not been assessed yet, it should be taken into account that as the time period between disturbances (e.g. drying events) increases, the interactions among the species may become more important (Schneider & Frost, 1996). Thus, biotic interactions in the most ephemeral pools may be weaker than in more permanent habitats. The environmental variables affecting diversity and the factors responsible for the differences in taxonomic richness among water bodies deserve further research.

Acknowledgements

References

Almirón, W. & M. E. Brewer, 1996. Classification of immature stage habitats of Culicidae (Diptera) collected in Córdoba, Argentina. Mem. Inst. Oswaldo Cruz 91: 1–9.

Almirón, W. & R. E. Harbach, 1996. Taxonomy and biology of *Culex (Culex) maxi* Dyar (Diptera: Culicidae) in South America. Mem. Inst. Oswaldo Cruz 91: 579–588.

Angrisano, E. B. & E. R. Trémouilles, 1995. Insecta Diptera. In Lopretto, E. C. & G. Tell (eds), Ecosistemas De Aguas Continentales. Metodologías para su estudio. 3, Ediciones Sur, La Plata: 1243–1265.

Bachmann, A. O. & E. B. Angrisano, 1998. Diversidad y bionomía de insectos acuáticos. Curso de postgrado, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires. MS: 289 pp.

Bachmann, A. O. & S. A. Mazzucconi, 1995. Insecta Heteroptera (=Hemiptera s. str.). In Lopretto, E. C. & G. Tell (eds), Ecosistemas De Aguas Continentales. Metodologías para su estudio. 3, Ediciones Sur, La Plata: 1291–1325.

Bazzanti, M., S. Baldoni & M. Seminara, 1996. Invertebrate macrofauna of a temporary pond in Central Italy: composition, community parameters and temporal succession. Arch. Hydrobiol. 137: 77–94.

Bazzanti, M., M. Seminara & S. Baldoni, 1997. Chironomids (Diptera: Chironomidae) from three temporary ponds of different wet phase duration in central Italy. J. Freshwat. Ecol. 12: 89–99.

Darsie, R. F. Jr., 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.

Del Ponte, E. & J. C. Blaksley, 1947. Importancia sanitaria de los Culicidae de la ciudad de Buenos Aires. La Prensa Médica Argentina 34: 821–824.

Elliott, J. M., 1977. Some methods for the statistical analysis of samples of benthic invertebrates. 2nd edn. Sci. Publ. Freshw. Biol. Assoc. U.K., 25: 1–156.

Fernando, C. H. & D. Galbraith, 1973. Seasonallity and dynamics of aquatic insects colonizing small habitats. Verh. int. Ver. Limnol. 18: 1564–1575.

Ludueña Almeida, F. F. & D. E. Gorla, 1995. The biology of *Aedes (Ochlerotatus) albifasciatus* Macquart, 1838 (Diptera: Culicidae) in Central Argentina. Mem. Inst. Oswaldo Cruz 90: 463–468.

Manso Soto, A. E. & A. Martínez, 1948. Estudios sobre mosquitos de la Ciudad de Buenos Aires. Misión Estudios Patología Regional Argentina 19: 39–49.

Manso Soto, A. E. & A. Martínez, 1949. Estudios sobre mosquitos de la Ciudad de Buenos Aires. Misión Estudios Patología Regional Argentina 20: 53–61.

Merrit, R. W. & K. W. Cummins, 1984. An introduction to the aquatic insects of North America. 2nd edn. Kendall/Hunt, Dubuque, Iowa: 722 pp.

Nilsson A. N., 1986. Community structure in the Dytiscidae (Coleoptera) of a northern Swedish seasonal pond. Ann. zool. fenn. 23: 39–47.

Nilsson A. N. & B. W. Svensson, 1994. Dytiscid predators and culicid prey in two boreal snowmelt pools differing in temperature and duration. Ann. zool. fenn. 31: 365–376.

Service, M. W., 1993. Mosquitoes (Culicidae). In Lane, R. P. & R. W. Crosskey (eds). Medical Insects and Arachnids. Chapman & Hall, London: 120–240.

Schneider, D. W. & T. M. Frost, 1996. Habitat duration and community structure in temporary ponds. J. n. am. Benthol. Soc. 15: 61–86.

Stout, V. M., 1964. Studies on temporary ponds in Canterbury, New Zealand. Verh. int. Ver. Limnol. 15: 209–214.

Trémouilles, E. R., A. Oliva & A. O. Bachmann, 1995. Insecta Coleoptera. In Lopretto, E. C. & G. Tell (eds), Ecosistemas De Aguas Continentales. Metodologías para su estudio. 3, Ediciones Sur, La Plata: 1133–1197.

Wellborn, G. A., D. K. Skelly & E. E. Werner, 1996. Mechanisms creating community structure across a freshwater habitat gradient. Ann. Rev. Ecol. Syst. 27: 337–363.

Wiggins, G. B., R. J. Mackay & I. M. Smith, 1980. Evolutionary and ecological strategies of animals in annual temporary pools. Arch. Hydrobiol. Suppl. 58: 97–206.

Williams, D. D. & B. W. Feltmate, 1992. Aquatic Insects. Cab International, Wallingford: 358 pp.

Williams, D. D., 1996. Environmental constraints in temporary fresh waters and their consequences for the insect fauna. J. n. am. benthol. Soc. 15: 634–650.

Williams, D. D., 1997. Temporary ponds and their invertebrate communities. Aquat. Conserv.: Mar. freshwat. Ecosys. 7: 105–117.

Zar, 1984. Biostatistical Analysis. 2nd edn. Prentice-Hall, Inc., Englewood Cliffs, N.J.: 718 pp.