Hydrobiologia **524:** 91–102, 2004.

Study of the insects associated with the floodwater mosquito *Ochlerotatus albifasciatus* (Diptera: Culicidae) and their possible predators in Buenos Aires Province, Argentina

Raúl E. Campos*, Liliana A. Fernández & Victoria E. Sy
Instituto de Limnología "Dr. Raúl A. Ringuelet", Universidad Nacional de La Plata, CC 712 (1900) La Plata, Buenos Aires, Argentina
*(*Author for correspondence: Tel.: +54-11-4275-8564, Fax: +54-11-4275-7799, E-mail: rcampos@ilpla.edu.ar)*

Received 3 September 2003; in revised form 6 January 2004; accepted 12 January 2004

Key words: puddles, floodwater mosquito, *Ochlerotatus albifasciatus*, Culicidae, insect community, predator

Abstract

Insects associated with the floodwater mosquito *Ochlerotatus albifasciatus* (Diptera: Culicidae) were studied from intermittent puddles in temperate Argentina in an attempt to detect the main predators. Forty-one taxa occurred in the puddles from spring to fall. Coleoptera and Diptera were dominant and diverse. Ephemeroptera and Odonata were scarce in numbers and species, and Heteroptera occurred in low numbers of species and high abundance of individuals. The main predators of immature *O. albifasciatus* were detected on the basis of relative abundance (ISA index), ecological dominant groups, and species association ("I" index). *Liodessus* sp. and *Rhantus signatus signatus* (Coleoptera: Dytiscidae) were the most abundant predators in the puddles and *Liodessus* sp., *Lancetes marginatus* (Dytiscidae) and *Psorophora ciliata* (Culicidae) were the most frequent. *Liodessus* sp. and *O. albifasciatus* were the best associated species in all seasons. *Liodessus* sp. was indistinctly associated with all larval instars and pupae, while *R. signatus signatus*, *L. marginatus* and *Psorophora ciliata* were more associated with the pupal stage of the mosquito. *Desmopachria concolor* (Coleoptera: Dytiscidae), *Tropisternus lateralis limbatus* and *Tropisternus setiger* (Coleoptera: Hydrophilidae) were other potential predators inhabiting the puddles, but their relevance was minor.

Introduction

The insect predators are relevant components of trophic relationships occurring in aquatic habitats (Cummins, 1973; Wiggins, et al., 1980) and represent a natural control of mosquito populations (e.g. Jenkins, 1964; Service, 1973; Bay, 1974). James (1961) pointed out that immature mosquitoes are less exposed to natural enemies in temporary than in permanent ponds. In intermittent puddles, the even shorter permanence of the habitat makes it favorable for breeding of immature culicids as a consequence of the scarce exposure to predators (Laird, 1988).

Predator-prey relationships among aquatic insects were summarized by Bay (1974) highlighting immature mosquitoes as prey. Jenkins (1964) cited a conspicuous list concerning more than 200 insect predators of mosquito larvae from diverse regions of the world. Among the aquatic Coleoptera, dytiscid and hydrophilid larvae have been cited as the best potential predators as a result of their voraciousness and abundance (e.g. James, 1961, 1966; Nelson, 1977). On the other hand, notonectids (Heteroptera) are considered effective mosquito predators when they are abundant (Murdoch et al., 1984).

Studies from the Pampasic region were made by von Ellenrieder & Fernández (2000) who reported species composition and temporal changes in the occurrence of aquatic Coleoptera from permanent, semi-permanent, temporary and temporary shallow pools located in a natural environment. Similar studies referring to aquatic Heteroptera were carried out by von Ellenrieder & Perez Goodwyn (2000). On the other hand, Fischer et al. (2000) studied the seasonal dynamics and entomofauna in urban rain pools.

The interest in the rain pools and their insects and trophic relationships, is due to the fact that these are the principal habitats of *Ochlerotatus albifasciatus*, the most abundant floodwater mosquito in the Pampasic region.

O. albifasciatus is widely distributed in Argentina (Darsie & Mitchell, 1985) and is a pest in vast zones because it attacks humans and domestic mammals (Forattin, 1965). Moreover, it has high sanitary interest as vector of Western Equine Encephalitis (WEE) (Mitchell et al., 1987).

In this study the seasonal fluctuation of an insect community associated to *O. albifasciatus* immature stages was analyzed, highlighting their main predators in a natural area.

Materials and methods

The study area is located in Pereyra Iraola Provincial Park situated in the northeast of the Pampeana biogeographic area in Buenos Aires Province, Argentina. This woodland is composed of hundreds of species of natural and exotic trees, with extensive free areas covered by pastures. The climate is temperate (annual average, 13–17 °C) with rainfall throughout the year (Cabrera & Willink, 1980). During the study period, daily mean temperature ranged from 11.4 to 22.1 °C in the spring, 20.4 to 27.1 °C in the summer, and 6.6 to 19.3 °C in the fall. The rainfall in the same period was 144.5, 91.3, and 146.2 mm in the spring, summer and fall respectively.

The larval habitats selected for the study consisted of four puddles situated in open land. These puddles had a maximum surface area of 29 × 50 m and as much as 50 cm central depth, and remained waterlogged from 6 days in summer until more than 20 days in the fall. However, the insect community composition was only studied during the time that *O. albifasciatus* occurred in these puddles. The bottom of the puddles was covered by pasture and decaying tree leaves, but no aquatic vegetation was observed during the sampling time.

Sampling was performed using a 450 ml dipper. One hundred dips were taken every day from puddle inundation until all adult *O. albifasciatus* had emerged, or until the puddles became dry. Adult and immature insects were isolated in the field to prevent predation and cannibalism. Adult insects were killed and preserved in 70% commercial ethyl alcohol, while immature were carried alive to the laboratory in individual crystal plastic tubes to be reared and identified.

Since there are no keys to species identification for larvae of beetles, we assumed that they were the same species as the adults collected. When more than one species of each genus was found, larvae were grouped (e.g. larvae of *Tropisternus lateralis limbatus* and *Tropisternus setiger* were grouped as *Tropisternus* spp.).

The standardized index of species abundance ISA (Roberts & Hsi, 1979), that encompasses numerical abundance and spatial distribution, was used to study the diversity of the insect community. To compare the ISA values among seasons, the mean and the variance were calculated following Roberts & Hsi (1979) and then tested by one-way ANOVA.

Aquatic insects were classified in four categories on the basis of the frequency values (F) expressed as percentage and relative abundance (ISA). Categories (modified from Velasco et al. 1993) were: Fundamental ($F \geq 50\%$, ISA ≥ 0.50); Constant ($F \geq 50\%$, ISA < 0.50); Accessory ($F < 50\%$, $0.25 >$ ISA < 0.50) and Sporadic ($F < 50\%$, ISA < 0.25).

The association among species was estimated by the I index, which varies from −1 to +1 and takes into account the number of collected individuals (Southwood, 1966). Three comparisons were conducted: (1) to detect the main predators of immature *O. albifasciatus*, samples from all seasons were clustered and association with potential predators (Fundamental and Constant species) was measured. (2) Association between main predators and every stage of *O. albifasciatus* in each season was evaluated. This was possible because neither generation superposition nor large age overlap were observed in the mosquito. (3) Association between most abundant and frequent predators was measured because they could be competing for a prey.

Aquatic insects were classified according to functional feeding groups (i.e., modes of food acquisition) following Cummins & Merritt (1996); collector, macrophyte piercer, parasite, predator, scraper and shredder. To improve the interpretation, collectors were sub-grouped into three categories: collector (filterer), collector (gatherer), and collector (gatherer-filterer).

After the field study, the main predators associated with *O. albifasciatus* were selected and tested in laboratory to evaluate their effect on *O. albifasciatus*. The predators were collected from the puddles, and isolated without food in individual container during 24 h before the experiment. The preys were reared in laboratory from eggs obtained from adults collected in the field. The essay was carried out in Petri dishes (9 cm in diameter) with 50 ml of tap water at room temperature. One predator and 20 preys smaller than the predator were placed on each dish. Twenty-four hours before, the survival preys were counted. Five replicates were performed for each predator.

Among the predators tested only for *Psorophora ciliata* it is possible to identified remains of prey in the gut content. On this assumption, larvae of this predator were collected from the puddles, and immediately dissected according to Kazana et al. (1983), to detect *O. albifasciatus* larvae in the gut content.

Results

Taxonomic composition of the aquatic community

The aquatic community was mainly composed of insects, although gastropods (Mollusca), copepods (Crustacea), Acari (Arachnida), and amphibians (Vertebrata) were present.

Among aquatic insects, forty-one taxa of the orders Ephemeroptera, Odonata, Heteroptera, Coleoptera and Diptera (Appendix A) were found. Ephemeroptera and Odonata were scarce, and only appeared in the puddles in late spring. Among the Heteroptera, although Corixidae, Belostomatidae and Notonectidae were found, only one species of each family was present. Corixidans were the most frequent while the others only occurred once during the study period.

The most diverse order was Coleoptera, with 26 taxa belonging to six families, being Dytiscidae and Hydrophilidae those with major number of species. All Coleoptera species were collected as adults, but dytiscids and hydrophilids were also present as larval stages (Appendix A).

Diptera were the second important order with five families breeding in the puddles. The most frequent and abundant was the Culicidae, mainly represented by the floodwater mosquito *O. albifasciatus* (Appendix A).

Taxon abundance and frequency

A list of the species grouped by category is given in Table 1. Among the Fundamental species, *O. albifasciatus* and *Liodessus* sp., are relevant because they stayed during the whole year into this category. Others Fundamental species were absent during some seasons (e.g. *P. ciliata*), or changed to other category (e.g. *Rhantus signatus*). The Constant category was composed of few species nearly all the year, being species of *Tropisternus* the most frequent in this category. The Accessory species were the scarcest in the puddles. By contrast, the Sporadic category included the majority of species inhabiting the puddles.

The diversity was higher in summer (ISA = 0.61) than in spring (early: 0.20; late: 0.41) and fall (early: 0.21; late: 0.45). However, no significant differences were detected between samples ($P = 0.90$).

Species association

The association between *Liodessus* sp. and immature *O. albifasciatus* was the highest in all seasons ($I = 0.78$). *R. signatus signatus* ($I = 0.26$), *Desmopachria concolor* ($I = 0.26$) *Lancetes marginatus* ($I = 0.18$), *Tropisternus* spp. ($I = 0.10$) and *P. ciliata* ($I = 0.26$) showed less association with this mosquito.

At the beginning of the spring (Fig. 1) *Liodessus* sp. and *P. ciliata* were highly associated with all stages of *O. albifasciatus* ($I_{I+II} = 0.87$, $I_{III+IV} = 0.94$, $I_{Pupa} = 0.64$ and $I_{I+II} = 0.96$, $I_{III+IV} = 0.82$, $I_{Pupa} = 0.87$, respectively). *D. concolor* was more associated with first and second ($I_{I+II} = 0.78$), than with late larval instars ($I_{III+IV} = 0.66$) and pupae ($I_{Pupa} = 0.36$).

Table 1. Classification of taxa from intermittent puddles inhabiting by *Ochlerotatus albifascaitus* in spring, summer and fall in Pereyra Park

Season	Fundamental $F \geq 50\%$ ISA ≥ 0.50		Constant $F \geq 50\%$ ISA < 0.50		Accessory $F < 50\%$ $0.25 \geq$ ISA < 0.50		Sporadic $F < 50\%$ ISA < 0.25	
Early spring	*O. albifasciatus*	0.96	*P. cyanescens*	0.46			*Tropisternus* spp.	0.20
	Liodessus sp.	0.91	*S. platensis*	0.41			*T. succinctus*	0.17
	P. ciliata	0.64	*R. signatus*	0.32			*E. variegatus*	0.13
			D. concolor	0.22			*Culex* spp.	0.08
			T. lateralis	0.18			*M. haagi*	0.06
							Sciomyzidae	0.06
							Belostomatidae	0.04
							Copelatus sp.	0.03
							Enochrus spp.	0.03
							B. minimus	0.02
							Laccophilus spp.	0.02
							M. glaucus	0.02
							N. ovatus	0.02
							L. lugubris	0.01
							Notonectidae	0.01
Late spring	*O. albifasciatus*	0.86	*Tropisternus* spp.	0.46	*Culex* spp.	0.37	Odonata	0.21
	S. platensis	0.75			*D. concolor*	0.34	*E. variegatus*	0.19
	R. signatus	0.72			Ephemeroptera	0.30	*Suphisellus* sp.	0.14
	Liodessus sp.	0.52					*Enochrus* spp.	0.11
							Ephydridae	0.11
							B. chalcocephalus	0.09
							Chironomidae	0.04
							E. vulgaris	0.04
							O. crinifer	0.01
							Sciomyzidae	0.01
Summer	*O. albifasciatus*	0.98	*T. lateralis*	0.43			Sciomyzidae	0.15
	Liodessus sp.	0.93	*D. concolor*	0.40			*R. signatus*	0.14
	P. cyanescens	0.80					*D. paranensis*	0.08
	P. ciliata	0.53					*Pelonomus* sp.	0.08
	S. platensis	0.52					*Tropisternus* spp.	0.05
	O. crinifer	0.50					*Copelatus* sp.	0.02
							S. nigrinus	0.02
Early fall	*O. albifasciatus*	0.99			Stratiomyidae	0.28	*Culex* spp.	0.13
	Liodessus sp.	0.73					*L. marginatus*	0.09
	Sciomyzidae	0.60					*S. platensis*	0.09
							O. crinifer	0.05
							R. signatus	0.05
							T. setiger	0.02
							B. chalcocephalus	0.01

Continued on p. 95

Table 1. (*Continued*)

Season	Category							
	Fundamental $F \geq 50\%$ ISA ≥ 0.50		Constant $F \geq 50\%$ ISA < 0.50		Accessory $F < 50\%$ 0.25 ≥ ISA < 0.50		Sporadic $F < 50\%$ ISA < 0.25	
							Copelatus sp.	0.01
							Suphisellus sp.	0.01
Late fall	*O. albifasciatus*	1.00	*O. scapularis*	0.39	*Copelatus* sp.	0.29	*Culex* spp.	0.18
	O. crinifer	0.85	*E. variegatus*	0.33			*B. alternans*	0.16
	Liodessus sp.	0.84	*R. signatus*	0.31			*Haliplus* sp.	0.10
	L. marginatus	0.64	Sciomyzidae	0.28			*S. platensis*	0.09
							Laccophilus spp.	0.07
							T. setiger	0.07
							D. concolor	0.06
							Paracymus sp.	0.05
							Suphisellus sp.	0.05
							Tropisternus spp.	0.04
							T. succinctus	0.04
							Notonectidae	0.02
							P. cyanescens	0.02

F = frequency, ISA = index species abundance. The numbers indicate standardized ISA value.

By contrast *R. signatus signatus* proved to be mainly associated with the pupal stage $I_{Pupa} = 0.67$).

In late spring, both *Tropisternus* larvae, and *R. signatus signatus* were highly associated with early instars ($I_{I+II} = 0.96$, $I_{I+II} = 0.94$, respectively) while the association with late instars decreased ($I_{III+IV} = 0.58$, $I_{III+IV} = 0.56$, respectively). In contrast *Liodessus* sp. was better associated with late instars ($I_{III+IV} = 0.87$) than early instars ($I_{I+II} = 0.55$). In all species low or no association was observed with the pupae because they were only present during one day (Fig. 2).

In summer (Fig. 3), *P. ciliata* was less associated with early instars of *O. albifasciatus* ($I_{I+II} = 0.39$) than in spring, however it showed a high association with late instars and the pupal stage ($I_{III+IV} = 0.99$, $I_{Pupa} = 0.82$). *D. concolor* was highly associated with early instars of *O. albifasciatus* ($I_{I+II} = 0.99$) and the pupal stage ($I_{Pupa} = 0.74$) in contrast to spring. The association of *Liodessus* sp. was similar to that in spring ($I_{I+II} = 0.80$, $I_{III+IV} = 0.82$, $I_{Pupa} = 0.40$).

At the beginning of the fall (Fig. 4), *L. marginatus* was mainly associated with *O. albifasciatus* pupae ($I_{Pupa} = 0.64$), while in late fall (Fig. 5) was also well associated with third and four larval instars ($I_{III+IV} = 0.79$, $I_{Pupa} = 0.98$). *Liodessus* sp. was mainly associated with first and second larval instars ($I_{I+II} = 0.78$) in early fall (Fig. 4) and with all immature stages ($I_{I+II} = 0.78$, $I_{III+IV} = 0.97$, $I_{Pupa} = 0.87$) in late fall (Fig. 5).

Probability of two predators occurring together was estimated and the highest associations were between *Liodessus* sp. and *R. signatus signatus* (I = 0.68), *D. concolor* and *P. ciliata* (I = 0.62), *Tropisternus* spp. and *R. signatus signatus*, and *Tropisternus* spp. and *P. ciliata* (both, I = 0.57).

Functional feeding groups

Predators and collectors were the dominant groups in the puddles (Appendix A) with proportion that varied among seasons from 38 to 61%, and 26 to 54%, respectively.

Among the collectors, the gatherer-filterers were the main sub-group in nearly all seasons and were represented by *Ochlerotatus* spp. However the filterers, including *Culex* sp. and *Psorophora*

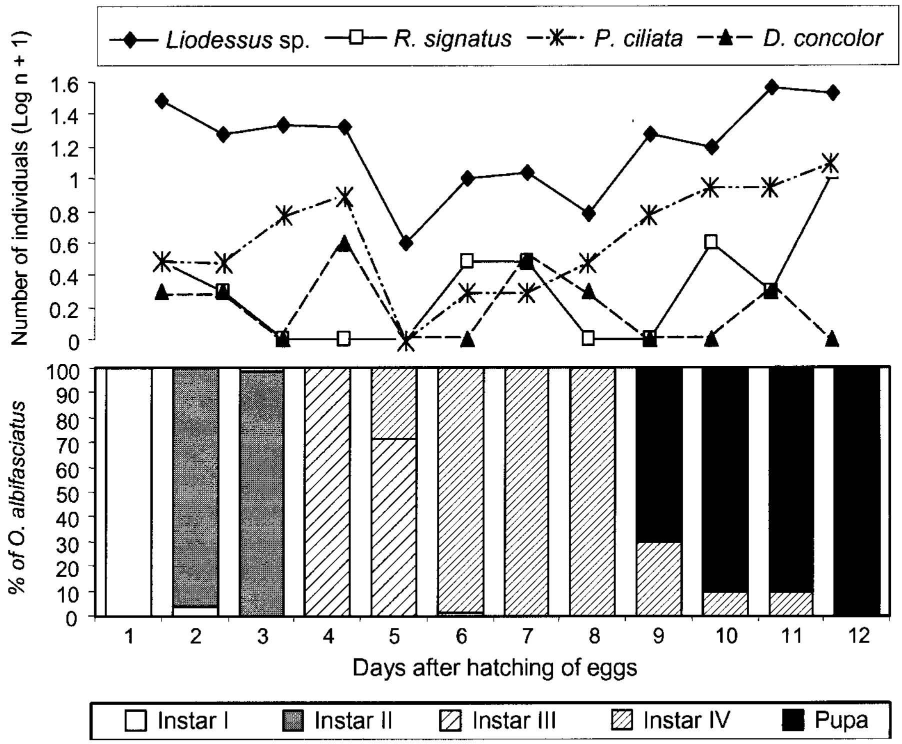

Figure 1. Age structure of *Ochlerotatus albifasciatus* and abundance of the main predators during early spring.

spp. were the main sub-group in early spring. Collector gatherers/macrophyte piercers, who included adult hydrophilids, were the second important sub-group in all seasons (Fig. 6).

The main predators were Dytiscidae, Hydrophilidae larvae, Noteridae, and *P. ciliata* (Culicidae) (Appendix A). Among the parasites or specific predators, only the sciomyzid larvae were present, occurring in all seasons associated to snails.

Predators of O. albifasciatus

All predators tested feed on *O. albifasciatus*. The mean number (± SD) of prey eaten from the more to least voracious predator were *R. signatus* (larva), 15 (±2.24); *P. ciliata*, 12.8 (±2.59); *Tropisternus* spp. (larva), 10 (±1.92); *D. concolor* (adult) and *Liodessus* sp. (adult), 6.4 (±1.14); *Liodessus* sp. (larva), 5.6 (±1.14).

From 77 *P. ciliata* larvae dissected (Instar: $n_{I} = 8$; $n_{II} = 25$, $n_{III} = 9$, and $n_{IV} = 35$) remains of *O. albifasciatus* were found in guts of one percent of instar III *P. ciliata* and 47% of instar IV. Others prey, including culicids different from *O. albifasciatus*, were found in the gut content.

Discussion

During the time the puddles were studied, the community was composed of organisms adapted to environmental fluctuations. Survival of crustaceans and mollusks after dry periods is possible because they remain as resting stages (e.g. cysts, eggs, or by becoming inactive). Other invertebrates adapt to short favorable conditions because of their fast immature development (e.g. Culicidae, Chironomidae), while others disperse opportunistically among ponds (Coleoptera and Heteroptera) (Fernando & Galbraith, 1973).

Heteroptera

The number of species found in the puddles was low, but individuals were abundant. The corixid

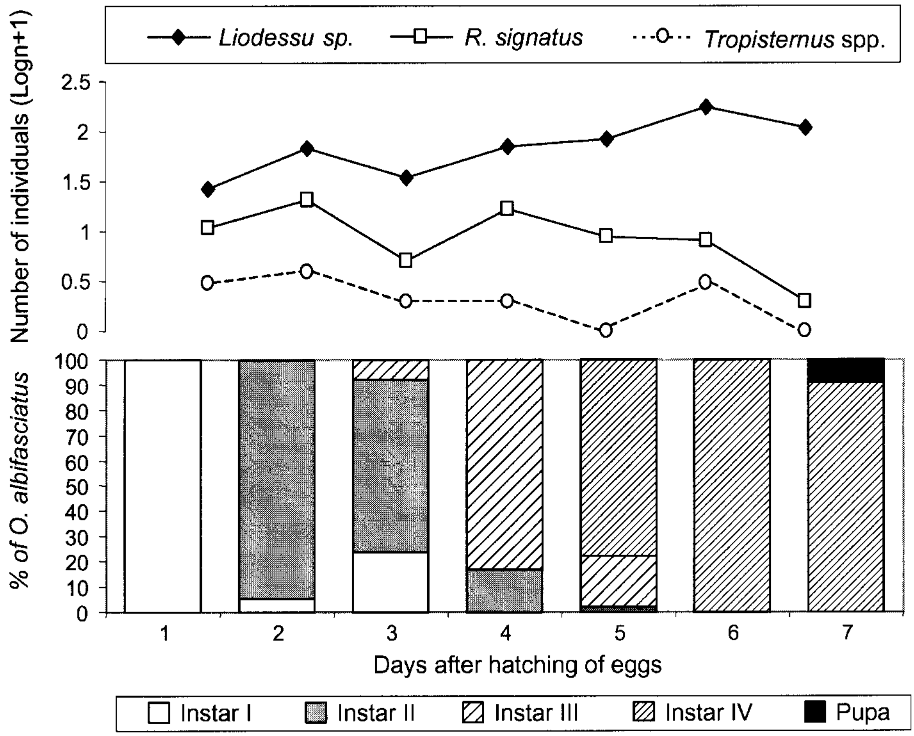

Figure 2. Age structure of *Ochlerotatus albifasciatus* and abundance of the main predators during late spring.

Sigara platensis was the most frequent and abundant species in all seasons. Fischer et al. (2000) obtained similar results from a study made in urban rain pools in Buenos Aires City. The quick colonization of the ephemeral puddles by this corixid is due to its aptitude to disperse from temporary or permanent pools by flying (Bachmann, 1981). In spite of the high association with *O. albifasciatus*, the effect on the mosquito was presumably not important because *S. platensis* is a collector feeding on fine particulate organic matter.

Coleoptera

Species of coleopterans inhabiting temporary shallow pools partially covered by floating aquatic plants (von Ellenrieder & Fernández, 2000), were also found in the puddles studied at Pereyra Park. However, amount and frequency of species were lower than in vegetated habitats. The early colonization by Dytiscidae and Hydrophilidae was favored by their skill at dispersion by flying (Fernando & Galbraith, 1973). The macrophyte piercer genera *Berosus*, *Derallus*, *Enochrus*, *Paracymus* and adult *Tropisternus* (Cummins & Merritt, 1996) were scarce and often found neither, in the puddles of Pereyra Park nor in urban rain pools (Fischer et al., 2000). The rare presence of these coleopterans in ephemeral puddles could be due to their preference for permanent and temporary vegetated habitats (von Ellenrieder & Fernández, 2000). On the other hand *Tropisternus* larvae, a predator, was abundant in all seasons in Pereyra Park. Its presence suggests that adult *Tropisternus* might reproduce in small habitats were prey abundance is high.

Liodessus sp., the smallest aquatic beetle inhabiting the puddles, was the earlier and most abundant colonist, probably because it is able to survive in mud crevices or debris when the puddles dry up. Because *Liodessus* sp. occurred in close association with *O. albifasciatus* and since it voraciously feeds on first and second instar larvae, it seems to be a relevant predator in nature. Another significant predator might be *R. signatus signatus*, whose larvae are fast swimmers and develop rapidly, as was observed during late spring

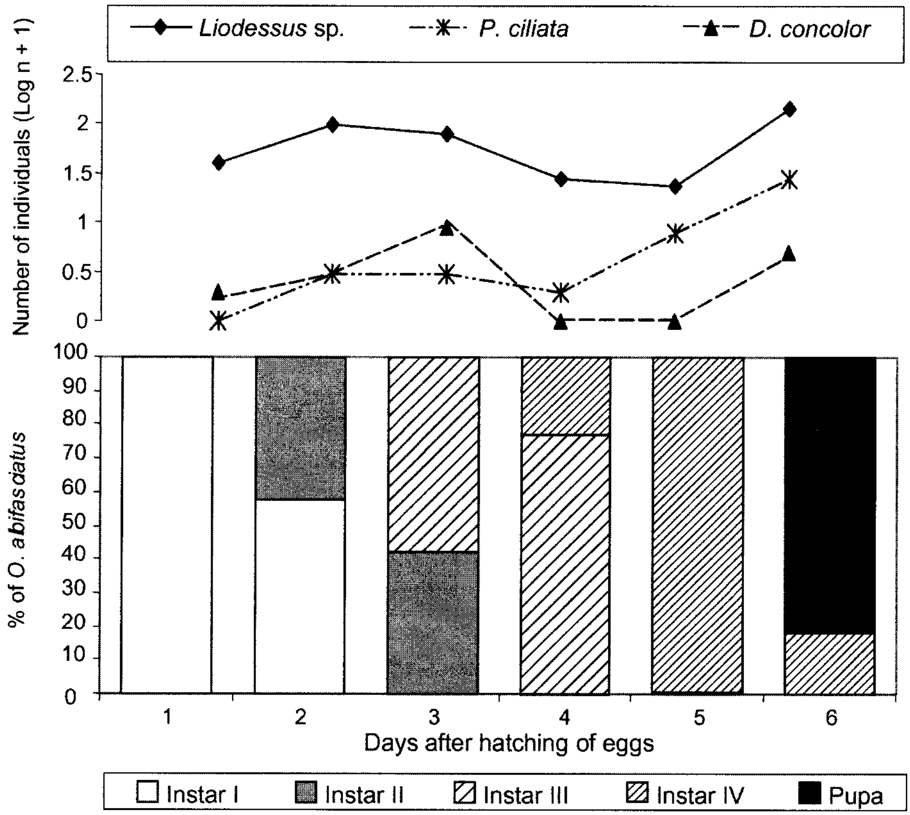

Figure 3. Age structure of *Ochlerotatus albifasciatus* and abundance of the main predators during summer.

sampling. Fischer et al. (2000) observed that *Liodessus* sp. and *R. signatus signatus* were also abundant and were present during the whole year in rain pools. On the other hand, they cited *Thermonectus succinctus* as abundant, however it was scarce in Pereyra Park.

L. marginatus was found in the puddle during fall. This conspicuous dytiscid could be performing important predatory pressure on *O. albisfasciatus*, since it was dominant and remained associated with late instars of this mosquito when the population level was highest.

D. concolor has been collected from permanent, temporary and shallow pools, where it was scarce (von Ellenrieder & Fernández, 2000). In the puddles of Pereyra Park *D. concolor* was frequent with seasonal variations in its abundance. In both spring and summer it was Constant, and only in late fall it was Sporadic. This small dytiscid was highly associated with first and second instar *O. albifasciatus* and seems to be a predator of this culicid from the bioassay carried out in laboratory.

The erratic occurrence of *Copelatus* sp., *Laccornellus lugubris*, *Macrovatellus haagi*, *Megadytes glaucus*, and *Thermonectus succinctus* in the puddles indicates that these dytiscids might not be relevant as predators of *O. albifasciatus*.

Haliplidae are principally algal feeders (Wiggins et al., 1980), macrophyte piercers and herbivore shredders (Cummins & Merrit, 1996). The low diversity and occurrence of this family in the puddles could be due to the lack of available food.

Von Ellenrieder & Fernández (2000) cited three species (two unidentified) of Noteridae occurring indistinctly in permanent, temporary and shallow pools in the Pampasic region, with major abundance and frequency in shallow pools. However, in puddles of Pereyra Park *Suphisellus nigrinus*, and two unidentified species of Noteridae, occurred sporadically. Although *Suphisellus* spp. preys on

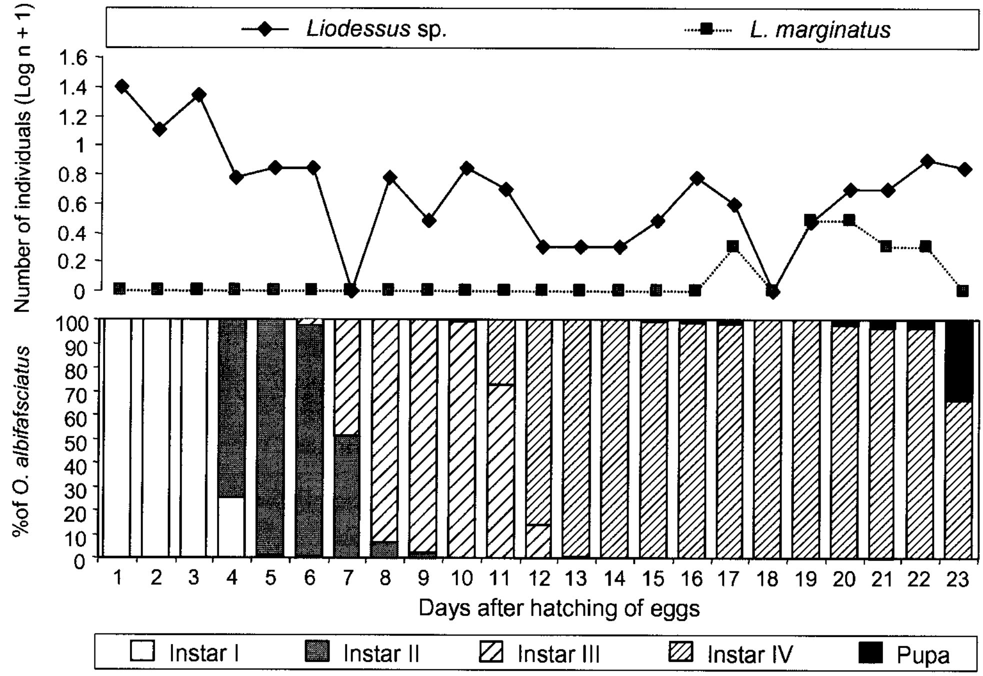

Figure 4. Age structures of *Ochlerotatus albifasciatus*, and abundance of the predators during early fall.

mosquito larvae in the laboratory (unpublished data), they would not be potential predators of *O. albifasciatus* because of their late occurrence in the puddles (after the molt to pupa.).

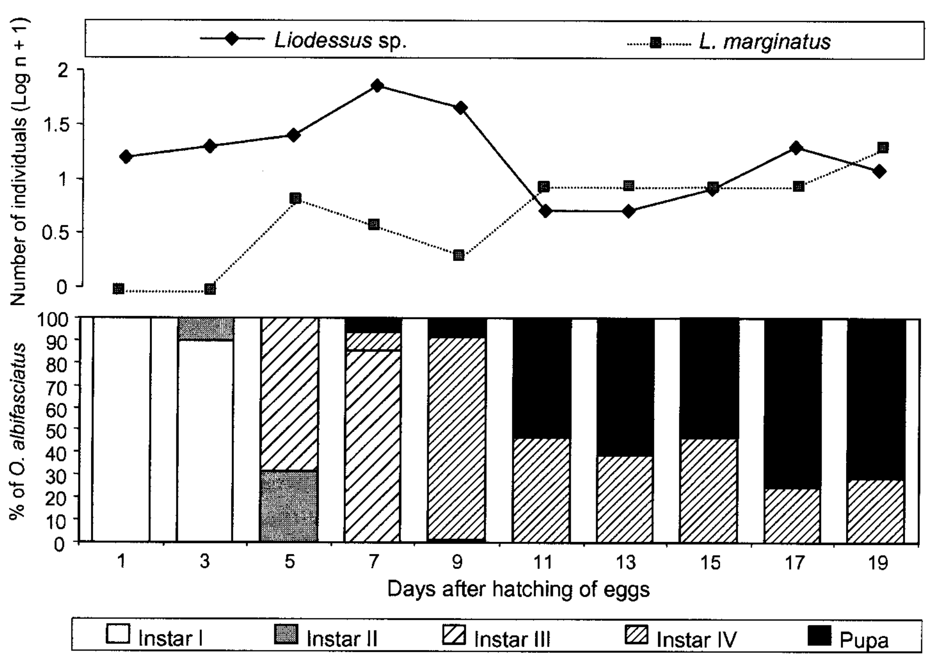

Figure 5. Age structures of *Ochlerotatus albifasciatus*, and abundance of the predators during late fall.

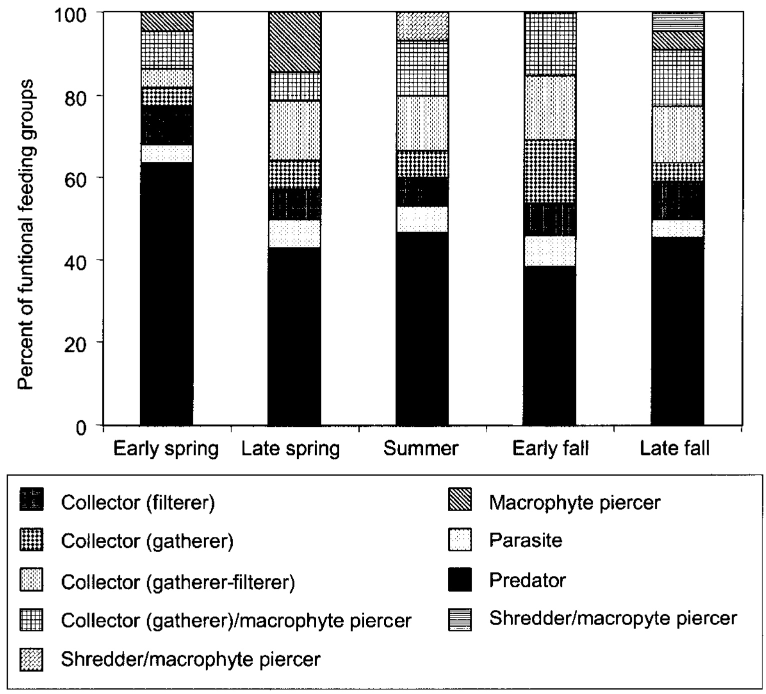

Figure 6. Functional feeding groups of insects inhabiting ephemeral puddles at Pereyra Park, Buenos Aires, Argentina.

Diptera

Species of both *Ochlerotatus* and *Psorophora* are multivoltine in temperate Argentina, and the number of generations produced depends on the frequency of flooding of eggs and success of hatching (Campos et al., 1995; Maciá et al., 1995; Fontanarrosa et al., 2000). Stimulant factors for floodwater mosquito eggs to hatch (unknown at present) are presumably the determinant of seasonal occurrence of larvae in the puddles.

Maciá et al. (1995) related a high increase in the abundance of immature *Ochlerotatus crinifer* from spring until fall, and a decrease in winter. In the present study *O. crinifer* was scarce in spring and summer, but in fall it was the second more abundant insect in the puddles. *O. albifasciatus* and *Ochlerotatus scapularis* coexisted with it. From the high abundance, synchronic development, and similar feeding habit of the three species, a strong competition between them is suggested, at least during fall.

Psorophora ciliata and *Psorophora cyanescens* occurred in the puddle in spring and summer when immature *O. albifasciatus* were highly abundant. Although *P. cyanescens* and *O. albifasciatus* are collectors (gatherers-filterers), the competence between them seems to be low, since *P. cyanescens* is a planctonic swimmer while *O. albifasciatus* is a diving swimmer who feeds in many microhabitats. On the other hand, the predator *P. ciliata* could be producing an important impact on the *O. albifasciatus* population, as a consequence of the narrow association observed with all larval instars. The remains of *O. albifasciatus* larvae found in the gut of *P. ciliata* larvae collected from the puddles also support this suggestion.

Most *Culex* species inhabit permanent or temporary habitats in Buenos Aires Province (Campos et al., 1993; Maciá et al., 1997). Occurrence in ephemeral puddles was not often observed during this study. *Culex* larvae were observed when the habitat acquired characteristics of temporary pools (more than 11 days after flooded), by the time *O. albifasciatus* had pupated (Campos & Sy, 2003). This asynchrony being suggests competition between neither *Culex* and *O. albifasciatus* nor *Culex* and other floodwater mosquitoes. Our result contrasts with Fischer et al. (2000) who found many individuals of *Culex* in rain pools. Because these authors did not indicate the duration of the pools, we suspect that those pools remained waterlogged longer than the pools studied in Pereyra Park. This presumption is supported by the taxa found by these authors (e.g. Hebridae, Ranatridae, Odonata) who are characteristic of vegetated temporary and permanent ponds.

Unidentified larvae of Sciomyzidae were abundantly collected from spring to fall, preying on small snails even though the puddle dried up on the 6th day. The presence of these Diptera in the ephemeral puddles is possible because they can deposit their eggs on emergent or shoreline vegetation and hence do not depend on the water surface for oviposition (Wiggins et al., 1980). Due the specificity with their prey, no interaction presumably occurred with *O. albifasciatus*.

Other taxa

Ephemeral puddles were poorly attractive to other groups such as Ephemeroptera, Odonata, and Heteroptera (Belostomatidae and Notonectidae), although abundant prey occurred. These groups were scarce and occurred later than the others in the puddles, possibly because of the lack of aquatic vegetation that causes a major stability of the environment. Our findings agree with those of Velasco et al. (1998) who reported that these taxa colonize the habitats at the end of the ecological succession.

From these results on abundance, frequency and association of species, we conclude that the most relevant predators of immature *O. albifasciatus* in intermittent and ephemeral puddles are the Dytiscidae *Liodessus* sp., *L. marginatus*, *R. signatus signatus* and the Culicidae *P. ciliata*, followed by the Dytiscidae *D. concolor* and the Hydrophilidae *T. lateralis limbatus* and *Tropisternus setiger*.

Acknowledgements

We thank Drs A. Bachmann (Universidad de Buenos Aires) for determination of Corixidae, and A. Rodrigues Capítulo and A. Maciá (Universidad Nacional de La Plata, Argentina) for critical review. This research was supported by a Grant from Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina. This is a contribution of the Instituto de Limnología Journal Serie No. 742.

Appendix A

Taxonomic classification of the insect inhabitants of the puddles (l: larva, a: adult, U: undetermined genus and species) and functional feeding groups (Cf: collector-filterer, Cg: collector-gatherer, Cgf. collector gatherer and filterer, Mp: macrophyte piercer, Pa: parasite, Pr: predator, Sc: scraper, Sh: shredder).

Ephemeroptera[lU] (Cg). Odonata[lU] (Pr). Heteroptera: Corixidae *Sigara platensis*[la] Bachmann (Cg), Belostomatidae *Belostoma* sp.[laU] (Pr), Notonectidae[aU] (Pr). Coleoptera: Dytiscidae (Pr) *Copelatus* sp.[la], *Desmopachria concolor*[a] Sharp, *Laccophilus* spp.[a], *Laccornellus lugubris*[a] (Aubé), *Lancetes marginatus*[a] (Steinheil), *Liodessus* sp.[la] *Macrovatellus haagi*[a] (Wehncke), *Megadytes glaucus*[a] (Brullé), *Rhantus signatus signatus*[la] (Fabricius), *Thermonectus succinctus*[a] Aubé, Gyrinidae *Neogyrinus ovatus*[a] (Aubé) (Pr), Noteridae *Suphisellus nigrinus*[a] (Aubé) (Pr), *Suphisellus* sp.[a] (Pr), Haliplidae *Haliplus* sp.[a] (ShMp), Hydrophilidae *Berosus alternans*[a] Brullé (CgMp), *Berosus minimus*[a] Knisch (CgMp), *Berosus chalcocephalus*[a] Germain (CgMp), *Derallus paranensis*[a] Oliva (CgMp), *Enochrus variegatus*[a] (Steinheil) (Mp), *Enochrus vulgaris*[a] (Steirnheil) (Mp), *Enochrus* spp.[l] (CgPr), *Paracymus* sp.[a] (CgMp), *Tropisternus lateralis limbatus*[a] (Brullé) (CgMp), *Tropisternus setiger*[a] (Germar) (CgMp), *Tropistemus* spp.[l] (Pr), Dryopidae *Pelonomus* sp.[a] (CgS). Diptera: Culicidae *Ochlerotatus albifasciatus*[l] (Macquart) (Cgf), *Ochlerotatus crinifer*[l] (Theobald) (Cgf), *Ochlerotatus scapularis*[l] (Rondoni) (Cgf), *Culex* sp.[l] (Cf), *Psorophora ciliata*[l] (Fabricius) (Pr), *Psorophora cyanescens*[l] (Coquillett) (Cf), Ephydridae[lU] (Cg), Chironomidae[lU] (Cg), Sciomyzidae[lU](Pa), Stratiomyidae[lU] (Cg).

References

Bachmann, A. O., 1981. Insecta Hemiptera Corixidae. In Ringuelet, R. A. (ed.), Fauna de agua dulce de la República Argentina 35: 270 pp.

Bay, E. C., 1974. Predator-prey relationships among aquatic insects. Annual Review of Entomology 19: 441–453.

Cabrera, A. L. & A. Willink, 1980. Biogeografia de América Latina. Serie de Biología, Monografia 13. OEA, Washington, DC, 114 pp.

Campos, R. E., A. Maciá & J. J. García, 1993. Fluctuaciones estacionales de culícidos (Diptera) y sus enemigos naturales en zonas urbanas de los alrededores de La Plata, provinica de Buenos Aires. Neotrópica 39: 55–66.

Campos, R. E., A. Maciá & J. J. García, 1995. Seasonality of *Psorophora* spp. populations (Diptera: Culicidae) and survey of parasites and pathogens in Buenos Aires Province, Argentina. Acta Entomológica Chilena 19: 113–121.

Campos, R. E. & V. E. Sy, 2003. Mortality in immatures of the floodwater mosquito *Ochlerotatus albifasciatus* (Diptera: Culicidae) and effects of parasitism by *Strelkovimermis spiculatus* (Nematoda: Mermithidae) in Buenos Aires Province, Argentina. Memorias do Instituto Oswaldo Cruz 98: 199–208.

Cummins, K. W., 1973. Trophic relations of aquatic insects. Annual Review of Entomology 18: 183–206.

Cummins, K. W. & R. W. Merritt, 1996. Ecology and distribution of aquatic insects. In Merritt, R. W. & K. W. Cummins (eds), An Introduction to the Aquatic Insects of North America, Kendall/Hunt, Iowa: 74–86.

Darsie, R. F. & C. F. Mitchell, 1985. The mosquitoes of Argentina: Parts I and II. Mosquito Systematics 17: 153–360.

Fernando, C. H. & D. Galbraith, 1973. Seasonality and dynamics of aquatic insects colonizing small habitats. Verhandlungen Internationale Vereinigung Limnologie 18: 1564–1575.

Fischer, S., M. C. Marinone, M. S. Fontanarrosa, M. Nieves & N. Schweigmann, 2000. Urban rain pools: seasonal dynamics and entomofauna in a park of Buenos Aires. Hydrobiologia 441: 45–53.

Fontanarrosa, M. S., M. C. Marinone, S. Fischer, P. W. Orellano & N. Schweigmann, 2000. Effects of flooding and temperture on *Aedes albifasciatus* development time and larval density in two rain pools at Buenos Aires University City. Memorias do Instituto Oswaldo Cruz 95: 787–793.

Forattini, O. P., 1965. Entomologia Médica Vol. 2, Universidade de São Paulo, São Paulo, 506 pp.

James, H. G., 1961. Some predators of *Aedes stimulans* (Walk) and *Aedes trichurus* (Dyar) (Diptera: Culicidae) in woodland pools, Canadian Journal of Zoology 39: 533–540.

James, H. G., 1966. Insect predators of univoltine mosquitoes in woodland pools of the Pre-Cambrian shield in Ontario, Canadian Entomology 98: 550–555.

Jenkins, D. W., 1964. Pathogens, parasites and predators of medically important arthropods. Annotated list and bibliography, WHO, Genève, 150 pp.

Kazana, M., C. E. Machado-Allison &. L. A. Bulla, 1983. Preferencias alimentarias de *Toxorhynchites theobaldi* (Diptera: Culicidae). Acta Científica Venezolana 34: 151–158.

Laird, M., 1988. The Natural History of Larval Mosquito Habitats. Academic Press, London, 555 pp.

Maciá, A., J. J. García & R. E. Campos, 1995. Bionomía de *Aedes albifasciatus* y *Ae. crinifer* (Diptera: Culicidae) y sus enemigos naturales en Punta Lara, Buenos Aires. Neotrópica 41: 43–50.

Maciá, A., J. J. García, & R. E. Campos, 1997. Variación estacional de tres especies de *Culex* (Diptera: Culicidae) y sus parásitos y patógenos en Punta Lara, provinicia de Buenos Aires, Argentina. Revista de Biología Tropical 44/45: 267–275.

Mitchell, C. J., T. P. Monath, M. S. Sabattini, J. F. Daffner, C. B. Cropp, C. H. Calisher, R. F. Darsie Jr. & W. L. Jakob, 1987. Arboviruses isolations from mosquitoes collected during and after the 1982–1983 epizootic of Western Equine Encephalitis in Argentina. American Journal of Tropical Medicine and Hygiene 36: 107–113.

Murdoch, W. W., M. A. Scott & P. Ebsworth, 1984. Effects of the general predator, Notonecta (Hemiptera) upon a freshwater community. Journal of Animal Ecology 53: 791–808.

Nelson, F. R. S., 1977. Predation on mosquito larvae by beetle larvae, *Hydrophilus triangularis* and *Dytiscus marginalis*. Mosquito News 37: 628–630.

Roberts, D. R. & B. P. Hsi, 1979. An index of species abundance for use with mosquito surveillance data. Environmental Entomology 8: 1007–1013.

Service, M. W., 1973. Mortalities of the larvae of the *Anopheles gambiae* Giles complex and detection of predators by the precipitin test. Bulletin of Entomological Research 62: 359–369.

Southwood, T. R. E., 1966. Ecological methods with particular reference to the study of insects populations. Methuen, London: xviii + 391 pp.

Velasco, J., A. Millán & L. Ramírez-Díaz, 1993. Colonización y sucesión de nuevos medios acuáticos I. Composición y estructura de las comunidades de insectos. Limnética 9: 73–85.

Velasco, J., M. L. Suárez, & M. R. Vidal-Abarca, 1998. Factores que determinan la colonización de insectos acuáticos en pequeños estanques. Oecologia Aquatica 11: 87–99.

Von Ellenrieder, N. & L. A. Fernández, 2000. Aquatic coleoptera in the Subtropical-Pampasic ecotone (Argentina, Buenos Aires): species composition and temporal changes. Coleopterists Bulletin 54: 23–35.

Von Ellenrieder, N. & P. J. Perez Goodwyn, 2000. Species composition and temporal variation of aquatic Heteroptera (Insecta) in the Subtropical-Pampasic ecotone in Argentina. Revista Brasilera de Entomología 44: 43–50.

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