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Odonata Diversity and Synanthropy in Urban Areas: A Case Study in Avellaneda City, Buenos Aires, Argentina

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Abstract

The increase of human population, especially in urban areas, correlates with an alarming destruction of green spaces. Therefore, understanding the mechanisms by which urbanization processes affect biodiversity is crucial in integrating the environment in a proper urban planning. The main urban center of Argentina is known as the Greater Buenos Aires (GBA), and it includes the autonomous city of Buenos Aires and 24 surrounding districts. Avellaneda, one of the districts of the GBA, is an important urban and industrial center with green areas and low level of urbanization on the coastal area of the Río de la Plata. This paper provides the first Odonata inventory for Avellaneda, determines the species' level of synanthropy with the Nuorteva index, and assess the Odonata species replacement along a latitudinal gradient on the occidental margin of the Río de la Plata.

Introduction

It is a well-known phenomenon that the increase of human population, especially in urban areas, correlates with an alarming destruction of green spaces (Mensah 2014). Large parcels of land are devegetated, paved, and dramatically modified in ways that often greatly exceed habitat changes that occur from logging, traditional farming, and many other land uses (Marzluff & Ewing 2001). Although many human activities promote biotic homogenization, urbanization is one of the most homogenizing activities of all (McKinney 2006). Therefore, understanding the mechanisms by which urbanization processes affect biodiversity, in particular how the biota responds to alteration of their habitats, is crucial in integrating the environment in proper urban planning (Goertzen & Suhling 2013).

Dragonflies and damselflies are conspicuous freshwater insects with hemimetabolous cycles that inhabit a wide variety of aquatic habitats. They have been recognized as excellent model organisms for environmental characterization and monitoring because of their attractive appearance, their sensitivity to different stressors, their complex life cycles with aquatic larva and terrestrial adults, and the feasibility of identifying species in the field (Clark & Samways 1996, Corbet 1999, Clausnitzer 2003, Dijkstra & Lempert 2003, Oerteli 2008, Villalobos-Jiménez *et al* 2016). However, there are very few studies that focus on the effects of urbanization on the Odonata community in the Neotropical region (Monteiro Junior *et al* 2014, Monteiro Junior *et al* 2015). In Argentina, ecological studies of insects on urban ecosystems are still very scarce (Mariluis *et al* 1990, Schnack *et al* 1990, Schnak *et al* 1995, Vallvé *et al* 1996, Fischer *et al* 2000, Fontanarrosa *et al* 2004, Mulieri *et al* 2011).

The main urban center of Argentina is known as the Greater Buenos Aires (GBA), and it includes the autonomous city of Buenos Aires and 24 surrounding districts. It concentrates the third part of the Argentine population, approximately 12.8 millions of habitants, within a relatively small area (3000 km^2) (INDEC 2010). Avellaneda, one of the districts of the GBA, has an approximate surface of 55 km^2 and 340,000 habitants. It is an important urban and industrial center with a thin coastal strip on the west that has a wide variety of green areas, with gallery forest and grasslands, low level of urbanization, and many different wetlands. This landscape is very different in terms of biotic composition from the rest of the province because it has a tropical influence

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since it receives propagules from the Paraná River during flood pulses. The Paraná River biotic influence decreases sharply towards the south up to 35°18′S where marginal forests disappear (Ringuelet 1961). These features make Avellaneda an excellent urban ecosystem in which to carry out ecological studies.

The main objective of this paper is to provide an assessment of the biodiversity of Odonata in urban wetlands of Avellaneda. In particular, the aims are to (1) provide an inventory of the fauna of Odonata, (2) determine the species' level of synanthropy with the Nuorteva index (1963), and (3) assess the species replacement along a latitudinal gradient on the occidental margin of the Río de la Plata. The working hypotheses are (1) density and diversity decrease in relation to an increase in human density and (2) species richness declines from north to south with the decrease of the influence of flood pulses from the Paraná River.

Material and Methods

Study area

The GBA is located within the Pampa ecoregion which is characterized by horizontal plains or very soft undulations, dominated by grasslands of *Stipa*, *Poa*, *Piptochaetium*, and *Aristida*; it has a gentle slope towards the east and well-defined streams that flow into the Paraná River and Río de la Plata (Brown *et al* 2006). Most of the streams and rivers that run through the GBA are either entombed in sewer pipes or extremely polluted, making them unsuitable for most organisms to live in. In this context, only those coastal wetlands, most of them with different degrees of anthropization, host the majority of the indigenous biodiversity left.

The study area is the floodplain of the Río de la Plata in the Avellaneda District. This area has had many different land uses since the last century, from fruit and vegetable production to landfills. It is crossed by three streams which flow into the Río de la Plata: Riachuelo, which constitutes Avellaneda's northern limit and is one of the most polluted rivers of the world (Ronco *et al* 2008); Sarandí; and Santo Domingo, both also with a very high level of pollution. Their river mouths are located on a segment of 5500 m along the coast.

In order to determine the level of synanthropy and assess the species replacement along a latitudinal gradient, a total of five localities were chosen: three within Avellaneda with different degrees of anthropization (see below) and two on the coastal area of the Río de la Plata: Lower Delta of the Paraná River (DP) located 33 km to the north of Avellaneda and Punta Lara Natural Reserve located 32 km to the south (Fig 1).

The localities sampled are as follows:

1. *CEAMSE* (*Coordinación Ecológica Área Metropolitana Sociedad del Estado*) *artificial pond* (34°40′57.11″S–58°17′04.26″W) is an artificial pond on an aggregate extraction quarry of 30 ha and 10 m depth. The materials from the quarry were used in a nearby landfill, which was shut down in 2004. Since then, the quarry has been filled with water. As part of the shutdown program of the landfill, the margins of this pond have been reforested with alien and indigenous trees.
2. *Irrigation channel in Sarandí* (34°39′54.39″S–58°18′27.90″W) is a rural area surrounded by forest (with alien and indigenous species) with production of fruits and vegetables.
3. "*La Saladita*" *Municipal Reserve artificial pond* (34°40′16.56″S–58°20′26.82″W) is an artificial endorheic rectangular pond of 8 ha and 15 m depth, with grasslands on the shore. It was created at the beginning of the *XX*th century with the excavations made during the construction of the port in Dock Sud.
4. *Lower Delta of the Paraná River* (DP) (34°19′16.50″S–58°35′07.76″W) is a large wetland area close to Buenos Aires City. This area has a typical delta landscape including plenty of riverine and pond habitats and is encompassed by two main rivers (Paraná de las Palmas and Paraná Guazú) (Muzón *et al* 2015).
5. *Punta Lara Natural Reserve* (PLNR) (34°46′57.94″S–58°00′45.27″W) is a natural protected area of 6000 ha located 30 km south from Avellaneda. The landscape, gallery forest, and grassland are very similar to those of Avellaneda, but the anthropic pressure is very low compared to that of Avellaneda (Muzón *et al* 1990, von Ellenrieder 2000).

Sampling procedures

In order to meet the objectives of this paper, a combination of qualitative and quantitative samplings were made. The data obtained from qualitative samplings (together with reliable records in the literature) were used to assess the beta diversity among DP, Avellaneda, and PLNR, whereas the data from quantitative samplings were used to assess the level of synanthropy of the species recorded within Avellaneda.

Qualitative samplings of adults were made from October to April from 2012 to 2015 throughout Avellaneda since no information was available on the Odonata of the district. Adults were collected between 10:00 a.m. and 3:00 p.m. on sunny days because it is when the Odonata are most active, given the thermoregulatory limitations of the adults (De Marco & Resende 2002). Adults were identified in the field by means of closed-focus binoculars; voucher adult

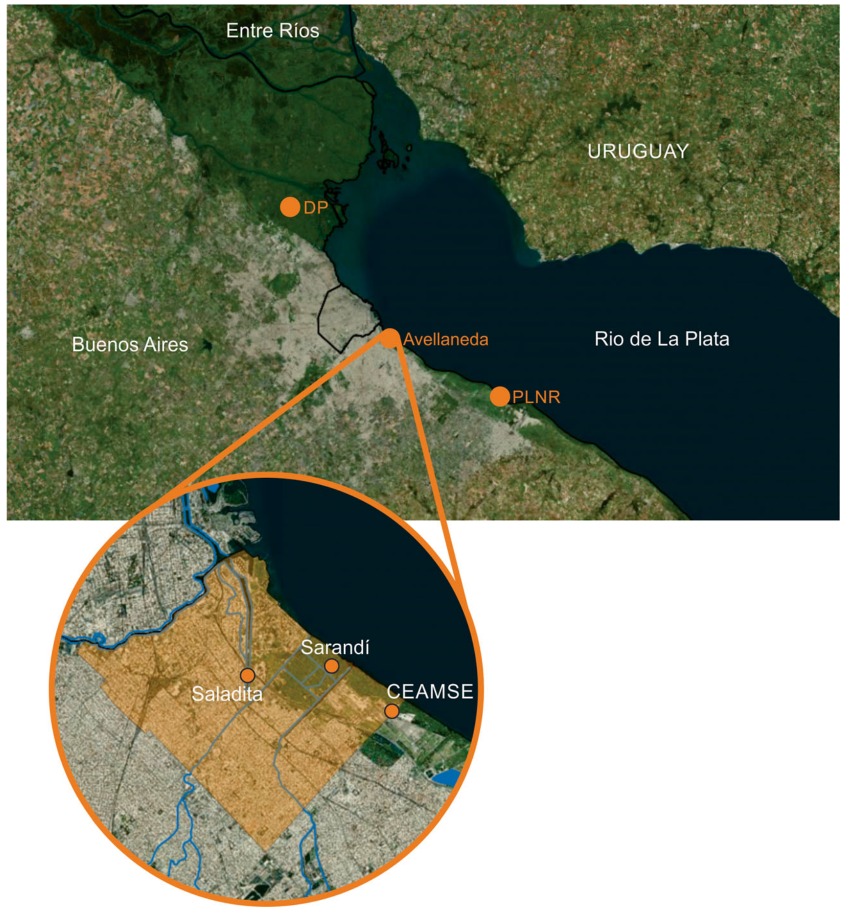

Fig 1 Map showing the localities sampled.

specimens were collected with aerial nets and preserved in acetone and then deposited in the BioGeA collection. A list of species for DP and PLNR was obtained from reliable records in the literature (Muzón *et al* 1990, Muzón *et al* 2015, von Ellenrieder 2000).

Six quantitative samplings (two on each locality) within Avellaneda were made during the summer (December to March) of 2013–2014 and 2014–2015. Species were recorded with closed-focus binoculars along ten transects of 10 m each as proposed by Simaika & Samways (2008, 2009).

Data analyses

Beta diversity. In order to assess the species replacement, Avellaneda was considered as a unit and similarity indexes were used to compare it to the external areas chosen (DP and PLNR). Biodiversity was quantified using the Shannon and Weaver index; the Jaccard similarity index and Cody index (1993) were used to compare Avellaneda with DP and PLNR.

Synanthropy. The Nuorteva index (1963) was used to estimate the degree of synanthropy of the species. This is an easy-to-use index that has been successfully applied to determine the level of synanthropy of dipterous insects (Schnack *et al* 1990, Mariluis *et al* 1990, Figueroa-Roa & Linhares 2004), spiders (Sacher 1983, Valesova-Zdarkova 1966), and birds (Nuorteva 1971). This index has two advantages: its application does not require a great amount of ecological data, and it can be adapted in relation to different gradients of urbanizations (Mollov 2014). The Nuorteva index requires an a priori classification of the sites in terms of human intervention based on the number of units of housing in an area. This represents an advantage because it can be adapted to different degrees of anthropic modification. The CEAMSE artificial pond was considered asynanthropic because there is no housing, the irrigation channel in Sarandí was considered hemisynanthropic, with few and scattered houses, and the La Saladita Municipal Reserve artificial pond was regarded as eusynanthropic because it is located within the urban area.

The degree of synanthropy (SI) can be calculated as

$$\mathrm{SI} = (2a + b - 2c)/2$$

where a is the percentage of individuals of a certain species recorded in the eusynanthropic site, b is the percentage of individuals of the same species recorded in the hemisynanthropic site, and c is the percentage of individuals

Table 1 List of species indicating their presence (X) or absence (–) in the *Lower Delta of the Paraná River* (DP), Avellaneda, and *Punta Lara Natural Reserve* (PLNR).

		DP	Avellaneda	PLNR
Coenagrionidae				
1	*Acanthagrion lancea* Selys, 1876	X	X (1, 2, 3)	X
2	*Andinagrion saliceti* (Ris, 1904)	X	–	–
3	*Argentagrion ambiguum* (Ris, 1904)	X	X (1, 2)	X
4	*Cyanallagma bonariense* (Ris, 1913)	X	X	–
5	*Homeoura chelifera* (Selys, 1876)	X	–	X
6	*Ischnura capreolus* (Hagen, 1861)	X	X	X
7	*Ischnura fluviatilis* Selys, 1876	X	X (1, 2, 3)	X
8	*Oxyagrion terminale* Selys, 1876	X	X (1, 2, 3)	X
9	*Peristicta forceps* Hagen in Selys, 1860	X	–	–
10	*Telebasis willinki* Fraser, 1948	X	–	X
Lestidae				
11	*Lestes spatula* Fraser, 1946	X	X (1)	X
12	*Lestes undulatus* Say, 1840	X	–	X
Aeshnidae				
13	*Rhionaeschna bonariensis* (Rambur, 1842)	X	X (1, 2, 3)	X
14	*Rhionaeschna confusa* (Rambur, 1842)	X	X	X
15	*Rhionaeschna planaltica* (Calvert, 1952)	X	–	X
16	*Staurophlebia bosqui* Navás, 1927	X	–	X
17	*Triacanthagyna nympha* (Navás, 1933)	X	–	–
Gomphidae				
18	*Aphylla distinguenda* (Campion, 1920)	X	–	–
19	*Phyllocycla argentina* (Hagen in Selys, 1878)	X	–	–
20	*Phyllocycla vesta* Belle, 1972	X	–	X
21	*Progomphus* sp.	X	–	–
Libellulidae				
22	*Brachymesia furcata* (Hegen, 1861)	–	X (1)	–
23	*Brachymesia herbida* (Gundlach, 1889)	–	X (1)	–
24	*Diastatops* sp.	X	–	–
25	*Erythemis attala* (Selys in Sagra, 1857)	X	–	X
26	*Erythemis plebeja* (Burmeister, 1839)	X	X (1)	X
27	*Erythemis vesiculosa* (Fabricius, 1775)	X	–	–
28	*Erythrodiplax corallina* (Brauer, 1865)	X	X (1)	–
29	*Erythrodiplax media* Borror, 1942	X	–	–
30	*Erythrodiplax melanorubra* Borror, 1942	X	–	X
31	*Erythrodiplax nigricans* (Rambur, 1842)	X	X (1, 2, 3)	X
32	*Erythrodiplax pallida* (Needham, 1904)	X	–	–
33	*Miathyria marcella* (Selys in Sagra, 1857)	X	X (1, 2)	X
34	*Micrathyria eximia* Kirby, 1897	X	–	–
35	*Micrathyria hypodidyma* Calvert, 1906	X	X (2, 3)	X
36	*Micrathyria longifasciata* Calvert, 1909	–	–	X
37	*Micrathyria ringueleti* Rodrigues Capítulo, 1988	–	–	X
38	*Micrathyria ungulata* Förster, 1907	X	–	–
39	*Nephepeltia flavifrons* (Karsch, 1889)	X	–	–
40	*Oligoclada laetitia* Ris, 1911	X	–	–
41	*Orthemis ambinigra* Calvert, 1909	X	–	X
42	*Orthemis cultriformis* Calvert, 1899	X	–	–
43	*Orthemis nodiplaga* Karsch, 1891	X	–	X
44	*Pantala flavescens* (Fabricius, 1798)	–	X (1)	X
45	*Perithemis icteroptera* (Selys in Sagra, 1857)	X	X (1, 2, 3)	X

Table 1 (continued.)

		DP	Avellaneda	PLNR
46	*Perithemis mooma* Kirby, 1889	X	–	X
47	*Planiplax erythropyga* (Karsch, 1891)	–	X (1)	–
48	*Tauriphila risi* Martin, 1896	X	X	X
49	*Tramea cophysa* Hagen, 1867	–	–	X

Numbers between parentheses indicate the localities within Avellaneda: 1 *CEAMSE artificial pond*, 2 *irrigation channel in Sarandí*, 3 "*La Saladita*" *Municipal Reserve artificial pond*.

of the same species recorded in the asynanthropic site. The SI varies from +100 (species highly associated with human environments) to −100 (species that completely reject human environments).

Results

The first list of Odonata for Avellaneda is included herein. A total of 20 species, seven Zygoptera and 13 Anisoptera, within four families were recorded (Table 1); *Brachymesia herbida* is recorded for the first time for Buenos Aires Province, and this is the southernmost record of the genus. The Shannon and Weaver index calculated for the localities of Avellaneda supports the a priori classification of the level of synanthropy considered for the Nuorteva index. Locality 1 (CEAMSE artificial pond) has the highest biodiversity value ($H' = 1.83$; $N = 247$) with a total of 14 species, whereas locality 3 (La Saladita Municipal Reserve artificial pond) has the lowest value ($H' = 1.30$; $N = 172$) with eight species.

The SI was calculated for the six most abundant species (Table 2), and the densities of the other species were too low to apply the index. *Ischnura fluviatilis* is a generalist species widely distributed in South America categorized as Least Concern (LC) by the International Union for Conservation of Nature and Natural Resources (IUCN); it has the highest SI value (+40.85; $N = 191$) which is an indication that it prefers eusynanthropic environments. *Perithemis icteroptera*, restricted to Brazil, Paraguay, and Argentina and also categorized as LC by the IUCN, has the lowest SI value (−28.23; $N = 115$) which suggests that it is an asynanthropic species.

Table 2 SI value for the most abundant species.

Species	SI
Perithemis icteroptera	−28.23
Brachymesia furcata	−13.25
Erythemis attala	−7.82
Rhionaeschna bonariensis	6.58
Erythrodiplax nigricans	10.38
Ischnura fluviatilis	40.85

The Jaccard similarity index shows a greater similarity between Avellaneda and PLNR ($I_J = 0.51$) than between Avellaneda and DP ($I_J = 0.38$). This result is also supported by the Cody index, which resulted in a lower value between Avellaneda and PLNR ($\beta = 0.63$) than that between Avellaneda and DP ($\beta = 0.59$).

Discussion

Most of the species recorded in Avellaneda are from lentic habitats. The absence of lotic species (*Peristicta forceps* or most of the gomphid species) is probably due to the absence of healthy streams and rivers in the area. From the species recorded for DP, only 50% are present in Avellaneda, and from those recorded for PLNR, only 68% are present. Beta diversity values show a greater species replacement between Avellaneda and the other areas than those between DP and PLNR, evidencing the degree of impoverishment of Avellaneda.

Within Avellaneda, the results corroborate hypothesis 1 "density and diversity decrease in relation to an increase in human density." Seven species (*Lestes spatula*, *Brachymesia furcata*, *B. herbida*, *Erythemis plebeja*, *Erythrodiplax corallina*, *Pantala flavescens*, and *Planiplax erythropyga*) have been recorded only for the asynanthropic site (CEAMSE artificial pond), which has the highest Shannon and Weaver value ($H' = 1.83$; $N = 247$). This locality is within a closed landfill in which restoration measures have been taken since 2004 and anthropic pressure has been minimized. Even though there is no information available of the Odonata diversity when the landfill was active, these results suggest a high recovering capacity of the diversity within the asynanthropic site studied.

The eusynanthropic site (La Saladita Municipal Reserve artificial pond) has the lowest diversity value ($H' = 1.30$; $N = 172$). Only eight species have been recorded which represent 53% of the species compared to those present in the asynanthropic site. Besides, the results show that *I. fluviatilis*, the species with the highest SI value (+40.85), is the most abundant (48.25%). This species is the most common coenagrionid of Argentina.

Beta diversity values contradict the working hypothesis 2 "species richness declines from north to south with the decrease of the influence of flood pulses from the Paraná River." Avellaneda is more similar to PLNR than to DP. The causes of the greater similarity of Avellaneda to PLNR were not assessed in this paper. However, two possible explanations can be inferred: (1) the autonomous city of Buenos Aires, located between DP and Avellaneda, could be interrupting the continuity of favorable habitats and isolating Avellaneda from the influence of the Paraná River, and (2) it is likely that in the GBA, and in particular in Avellaneda City, urban development has changed the landscape in such a way that there are not enough wetlands to host the Odonata diversity expected.

According to previous contributions (Goertzen & Suhling 2013), our results suggest than urban wetlands can host a significant specific diversity. Particularly, artificial ponds like that of CEAMSE landfill exhibit a high recovering capacity from the regional species pool. Biodiversity differences between close urban ponds like CEAMSE and La Saladita strongly suggest that, in an urban context, the sole presence of an aquatic habitat is not enough to promote biodiversity sustainability; there are other determinants (for example the degree of synanthropy), which need an appropriate management in order to improve both their environmental and conservational values.

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