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Diversity of Salticidae (Arachnida: Araneae) in the historical and natural reserve 'Martín García Island', Argentina

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ABSTRACT
From Martín García Island were collected 975 jumping spiders, from five environments, using beating net and manual sampling methods. *Saitis variegatus* Mello-Leitão, 1941 was the most abundant (24.62%). The sandy xerophilous forest had the highest species richness (23 morphospecies) and jungle showed the greatest spider abundance (*n*: 384). The sandy area was the least diverse and the last in relative abundance. Salticids represented 16% of the species recorded from Argentina, and the second largest family registered. The spider fauna found could be similar to that of the Southern Brasilian region, as occurs with scorpions. Two genera and two species are new records for Argentina. In addition, three new species of jumping spiders, as well as the discovery of the unknown male and female of two species, were registered. There was no record of cosmopolitan spiders or those with a large distribution range on the Island.

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Introduction

Human activity impacts on natural ecosystems in a direct and irreversible way; therefore it also impacts on the diversity of species. Disturbance practices highly modify the environment by changing, for instance, vegetation structure, soil moisture and temperature regime. Biodiversity loss is the most important process of environmental change (Wilson 1992; Maelfait and Hendrickx 1998). Studies aimed at biodiversity conservation are the main subject under investigation, based on systematic, biological and ecological aspects (Crisci et al. 1993; Duelli and Obrist 2003). Constant urbanisation and the advance of farming modifies the natural landscape, which in combination with irresponsible recreational use, negatively impacts upon most of the native fauna populations. Martín García Island is a Historical and Natural Reserve; it is an important tourist centre with a regular human population. The impact of urbanisation is very difficult to evaluate on the island because of poor knowledge about the ecosystems' function and their taxocenosis. Martín García Island is also a biodiversity hotspot of Buenos Aires Province, because it has a wide variety of flora and environments (Lahitte and Hurrel 1994).

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Almost all arachnids are good ecosystem degradation indicators, because they are very sensitive to environmental changes caused by human activity. They are closely associated with environmental conditions and vegetation. Most spiders have specific ecological requirements, making them useful indicators of spatial and temporal variation in terrestrial ecosystems (Pearce and Venier 2006). They are important on the trophic networks as generalist predators, as well as by their abundance, biomass and species diversity (Wise 1993, 2002, 2006). They feed on all kinds of invertebrates and some small vertebrates, and they are eaten by birds, reptiles, amphibians and several groups of mammals. They succeeded in almost every terrestrial environment, and they are regulators of insect populations (Marc and Canard 1997; Haddad et al. 2004; Scioscia 2008; Chatterjee et al. 2009). Spiders are very important for ecological studies as environment quality indicators and as biological control agents in agroecosystems; therefore they are ideal organisms for biological monitoring (Green 1999; Pearce and Venier 2006; Cristofoli et al. 2010).

Jumping spiders (Salticidae) are among the most numerous and diverse families of the order Araneae. It comprises 592 genera and 5615 described species, but it is known that there are many entities still unnamed; over 181 species are recorded from Argentina (Platnick 2015). Historically, in Argentina arachnid captures have not been accomplished periodically nor through intensive sampling in the same area at different times of the year, except for the works of Corronca and Abdala (1994), Rubio et al. (2004), Avalos et al. (2007, 2009), Grismado (2007), Grismado et al. (2011) and Ferretti et al. (2010, 2012). The purpose of this paper is to assess the species richness, relative abundance and alpha and beta diversity of salticid spiders among different habitats at the Historical and Natural Reserve 'Martín García Island'. Therefore, this study should be a great contribution to the knowledge of the family.

Materials and methods

Study area

Martín García Island is located at the northwest of the de La Plata River, near to the delta of the Parana River, 45 km from Buenos Aires City and 3.5 km from the Uruguay coast. The island has a rectangular shape, 3380 m length and 1700 m wide, of nearly 168 hectares, most of them being wild areas including a forest and a small urban settlement. The island constitutes a high fracture block of the crystalline basement of Brasilia, which with the Tandil crystalline basement are the most ancient in Argentina. Its highest point is at 25 m above sea level (34° 11′ 09″ S, 58° 15′ 09″ W). The weather is moderate and humid with an annual average temperature of 17°C and an average humidity level of 81% in June and July (Lahitte and Hurrel 1994).

Sampling'

Twelve field trips were carried out over 3 years, covering the 12 months of the year. The arachnids were captured by beating net and manual sampling in five different ecological environments: jungle (J), shore forest (SF), airport xerophilous forest (AXF), sandy xerophilous forest (SXF) and sandy area (SA). The J is characterised by hygrophilous conditions, related to coastal or inland zones; and it is phytogeographically similar to Parana River galleries (forest community with three tree strata, generally up to 20 m high; a shrub stratum, an herbaceous stratum and a muscinal stratum, there are also lot of lianas and epiphytes) (Lahitte and Hurrel 1994). The SF develops next to the southern coast of the island; it is characterised by mesophile forests of the riparian delta with riparian bushes and grasses. Dry forests exhibit dominant xeromorphic biotypes (spinous woody plants). These are low forests with a tree stratum, a shrub stratum and an herbaceous stratum, lianas and epiphytes. In this area can be found flooded soils with hydrophyte vegetation and sandy soils next to the sandy areas; therefore, dry forest can be divided into AXF (situated on the western edge of the landing strip, which is exposed to frequent winds and flooding) and SXF (protected from winds and with a higher temperature microclimate throughout the year). The SA has scarce and peculiar vegetation, with low and stunted plants.

The samples caught were each preserved separately in ethanol (80%), in airtight plastic containers with a label indicating the date, environment and the capture method. Genera and species identifications were performed using keys (Proszynski 2011), María Elena Galiano's descriptions and notes, and by comparison with reference material in the collections. Specimens were deposited at the National Collection of Arachnology (MACN-Ar) at the Arachnology Division of the Museo Argentino de Ciencias Naturales 'Bernardino Rivadavia' (MACN) and the Arthropod Collection of the Museo de La Plata (MLP-Ar).

Data analysis

To estimate alpha and beta diversity different parametric and non-parametric methods were used, using EstiMateS (version 9.1.0) (Colwell 2013), Biodiversity Pro (version 2) (McAleece et al. 1997) and PAST (version 2.12) (Hammer et al. 2012) software. Species richness (S) and relative abundance were manually calculated. Alpha diversity was estimated using the Margalef index, Shannon-Wienner index (H'), Simpson´s index (D) and Pielou´s equity index (J), and estimators such as Chao 1, Chao 2 and the first and second order of jacknife (Colwell and Coddington 1994; Moreno 2001) were also used. Beta diversity was calculated by the similarity coefficient indexes of Jaccard, Sorensen and Bray-Curtis (Magurran 1988; Magurran and McGill 2011).

Results

A total of 975 specimens were collected and separated into 29 morphospecies (mpsp) from 24 genera. Fifteen morphospecies were identified to a specific level (Table 1). About 88% of the individuals were captured using beating nets, belonging to 25 mpsp; 7.27% males, 9.57% females and 82.12% juveniles. The remaining 12% were captured by manual sampling, belonging to 26 mpsp; 21.15% males, 38.89% females and 48.15% juveniles. *Saitis variegatus* Mello-Leitão, 1941 was the most abundant species (24.62%), followed by *Chira gounellei* (Simon, 1902) (15.28%) and *Synemosyna aurantiaca* (Mello-Leitão, 1917) (10.67%). *Chira gounellei* and *Coryphasia* sp. were captured in all environments, while *Saitis variegatus* and *Synemosyna aurantiaca* were not found in SA. The remaining species did not exceed 8.5% of the total individuals captured.

Table 1. List of captured species and species´ abundance of the historical and natural Reserve Martín García Island (Buenos Aires, Argentina) environments.

Species	J	SF	AXF	SXF	SA	*n*	%
*Agelista andina**	24	5	1			30	3.08
Agelista n. sp.				1		1	0.10
*Aphirape flexa**	6	5	3	2		16	1.64
Bellota sp.	6		5	4		15	1.54
Breda cf. variolosa[1*]	1	3	5	1		10	1.03
Chira gounellei	77	23	21	25	3	149	15.28
Coryphasia sp.[+*]	8	1	1	7	1	18	1.85
Corythalia sp.			2	19	1	22	2.26
*Dendryphantes mordax**			1			1	0.10
*Euophrys saitiformis**			1	1		2	0.21
Euophrys sp.		1	3	3		7	0.72
*Euophrys sutrix**	4		4	12	2	22	2.26
Gastromicans albopilosa[+]	20	19	14	20		73	7.49
Helvetia sp.			1	2	2	5	0.51
*Lyssomanes pauper**	20	21	11	1		53	5.44
Metaphidippus sp. 1		1		5		6	0.62
Metaphidippus sp. 2			1	3		4	0.41
Metaphidippus sp. 3	1	2				3	0.31
Neonella sp.	5	4		4		13	1.33
*Phiale graciosa grupo**	1			1		2	0.21
*Saitis variegatus**	74	64	23	79		240	24.62
*Sarinda marcosi**	13	5	1			19	1.95
Scoturius n.sp.	5		2	1		8	0.82
Semora napaea [2+]	24	13	7	12		56	5.74
*Synemosyna aurantiaca**	59	27	13	5		104	10.67
Thiodina sp.	34	30	16			80	8.21
*Trydarssus pantherinus**				1		1	0.10
Tulpius aff. gauchus[+*]			6	6		12	1.23
Yepoella n. sp.	2	1				3	0.31
Total	384	225	142	215	9	975	100
%	39.43	23	14.58	22.07	0.92	100	
S	19	16	22	23	5		

J: jungle; SF: shore forest; AXF: airport xerophilous forest; SXF: sandy xerophilous forest; SA: sandy area. [+]new records for Argentina; *new records for the island; [1]non described female; [2]non described male.

Three new species of *Scoturius, Agelista* and *Yepoella* were recorded; the unknown male of *Semora napaea* Peckham and Peckham, 1892 and the unknown female of *Breda variolosa* Simon, 1901 were also identified. These findings will be described in a further systematic contribution. The genera *Coryphasia* and *Tulpius* are here cited as new records for Argentina, as well as the species *Gastromicans albopilosa* (Simon, 1903) and *S. napaea*. Except for *Chira gounellei*, the other 14 species are new records for the island. *Euophrys* and *Metaphidippus* were the genera with the highest species richness (three mpsp each), followed by *Agelista* (two mpsp); the remaining genera were represented by only one species.

The most diverse environment was AXF (H = 2.61) followed by J (H = 2.36), SXF (H = 2.29), SF (H = 2.23) and SA (H = 1.52). The nonparametric diversity indexes and the dominancy indexes showed the same trend (Table 2).

The Shannon´s diversity test showed significant differences between SA and AXF ($t = -2.39$; $p = 0.018$) and with SA ($t = 4.88$; p = 0.0007); between SF and AXF ($t = -3.59$; $p = 0.0004$) and with SA ($t = 4.15$; $p = 0.0017$); between both xeromorphic forests ($t = 2.68$; $p = 0.008$); between AXF and SA ($t = 5.65$; $p = 0.0001$); and between SXF and SA ($t = 2.68$; $p = 0.0077$). Non-significant differences were shown between J and SF

Table 2. Alpha diversity indexes for the environments of Martín García Island.

Index	J	SF	AXF	SXF	SA
n	384	225	142	215	9
S	19	17	22	23	5
H′	2.36	2.23	2.61	2.29	1.52
J′	0.7	0.66	0.78	0.68	0.45
Simpson's	0.88	0.86	0.91	0.82	0.77
Margaleff	3.03	2.95	4.24	4.1	1.82
Singleton's	3	4	7	7	2
Doubleton's	1	1	2	2	2
Chao 1	21 ± 3	20 ± 4	29 ± 7	30 ± 7	5.3 ± 0.9
Chao 2	22 ± 4	19 ± 3	26 ± 4	31 ± 7	6 ± 2
Jacknife 1	24 ± 2	22 ± 2	29 ± 3	32 ± 3	8 ± 2
Jacknife 2	26 ± 3	24 ± 2	32 ± 2	38 ± 2	9 ± 2

J: jungle; SF: shore forest; AXF: airport xerophilous forest; SXF: sandy xerophilous forest; SA: sandy area. *n*: number of specimens; S: species richness; H′: Shannon-Wienner; D: Simpson´s index; J: Pielou´s equity.

(t = 1.80; p = 0.07); between J and SXF (t = 0.96; p = 0.34); and between SF and SXF (t = –0.44; p = 0.66).

The highest relative abundance was for SA (n = 384), followed by SF (n = 225), SXF (n = 215) and AXF (n = 142); the least abundant zone was SA (n = 9)

Both xeromorphic forests showed the highest number of singletons. The SXF species represented by only one specimen were *Agelista* n. sp., *Breda variolosa, Euophrys saitiformis* Simon, 1901, *Lyssomanes pauper* Mello-Leitão, 1945, *Phiale gratiosa* group, *Scoturius* sp. and *Trydarssus pantherinus* (Mello-Leitão, 1946). The AXF species with only one specimen were *Agelista andina* Simon, 1900, *Coryphasia* sp., *Dendryphantes mordax* C.L Koch, 1846, *Euoprys saitiformis, Metaphidippus* sp. 2, *Helvetia* sp. and *Sarinda marcosi* Piza, 1937.

Considering the total number of spiders captured in each environment, the nonparametric estimators for J ranged between 21 (Chao 1) and 26 (second order jacknife) species, the observed richness (S_{obs}) being 19 species. Expected values for SF ranged between 19 (Chao 1) and 24 (second order jacknife), while the observed value was 17 species. Xeromorphic forest values ranged between 26 (first order jacknife) and 32 (second order jacknife) for AXF (S_{obs} = 22); and between 30 (Chao 1) and 38 (second order jacknife) for AXF (S_{obs} = 23). Finally, the expected richness values for SA ranged between 5.3 (Chao 1) and 9 (second order jacknife); while the observed richness was five species. (Table 2).

The beta diversity analysis showed that the environments with greater similarity were J and SF (Sorensen = 0.83; Jaccard = 0.71; Bray Curtis = 71.69) (Tables 3, 4 and 5). The lower similarity for Sorensen and Jaccard indexes was between SA and SF (0.18 and 0.10, respectively); whereas the Bray-Curtis analysis showed that the lower similarity was between SA and J (Bray-Curtis = 3.04). The remaining environment analysis showed values in between.

Table 3. Sorensen index for environments of Martín García Island.

Sorensen	SF	AXF	SXF	SA
J	0.83	0.73	0.67	0.25
SF		0.67	0.60	0.18
AXF			0.80	0.37
SXF				0.36

J: jungle; SF: shore forest; AXF: airport xerophilous forest; SXF: sandy xerophilous forest; SA: sandy area.

Table 4. Jaccard index for Martín García Island´s environments.

Jaccard	SF	AXF	SXF	SA
J	0.71	0.58	0.50	0.14
SF		0.50	0.43	0.10
AXF			0.67	0.23
SXF				0.22

J: jungle; SF: shore forest; AXF: airport xerophilous forest; SXF: sandy xerophilous forest; SA: sandy area.

Table 5. Bray-Curtis index for environments of Martín García Island.

Bray-Curtis	BR	BXAe	BXAr	A
S	71.69	46.01	53.67	3.04
BR		62.47	61.05	3.42
BXAe			54.24	10.74
BXAr				8.07

J: jungle; SF: shore forest; AXF: airport xerophilous forest; SXF: sandy xerophilous forest; SA: sandy area.

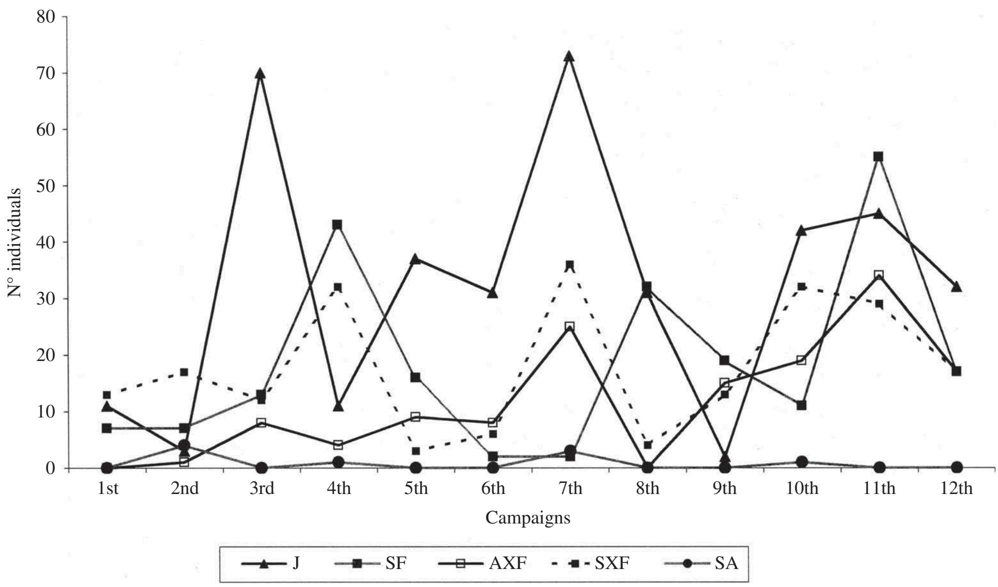

Figure 1. Number of spiders captured by environment on each sampling campaign at Martín García Island.

Regarding the temporal variation, in J more than 10 specimens were collected over all samplings, except for two captures, one in the second campaign (fall) and the other in the ninth campaign (winter), which recorded just three and two spiders respectively. The J showed an abundance peak in the seventh recollection (January, second year) (n = 73). In all other environments the greater number of specimens found corresponded to spring (fourth campaign) and summer months (seventh and eleventh campaigns) (Figure 1).

Discussion

The total of salticid morphoespecies occurring on Martin Garcia Island represented 16% of the species recorded from Argentina (Platnick 2015), being the second largest family, both in species richness and abundance of individuals, after Araneidae (Zvedeniuck 2009). Historically, it was assumed that much of the spider fauna of the island was to be consistent with the Argentinean Mesopotamia fauna, especially with the diversity from the Paraná delta. Against this, due to the distinct geological origin of both environments, it could be assumed that Martín García Island fauna could be different. In Argentina there are many extra-Andean orogenic systems, which have caught the attention of biogeographers because of the particular relationships shown by the biota (Roig–Junent et al. 2003). One of these is the system known as 'Peripampeanas Saws' (De La Sota 1967), 'Arch Orogenic Peripampásico' (Frenguelli 1950) or 'Trace Peripampásico' (Acosta 1989, 1993; Mattoni and Acosta 1997). These saws have been considered ancient orogenic systems that were related to associated systems in Southern Africa (Jeannel 1967; Cicchino and Roig–Junent 2001).

In South America this system describes an arc that begins in southern Brazil, continues in the southeastern saws of Uruguay, then in Argentina in Buenos Aires Province, in the Tandilia and Ventania systems, the saws of Córdoba Province (Pampa de Achala), ending in the subAndeans systems of Tucumán, Salta and Jujuy (Frenguelli 1950). Furthermore, it is presumed that these systems exhibited biotas with old connections that have subsequently undergone fragmentation, possibly during the Tertiary (Ringuelet 1961; Acosta 1989, 1993; Crisci et al. 1993; Mattoni and Acosta 1997).

Almeida et al. (1973) originally defined the Río de La Plata craton (RPC) to include the 'ancient cratonic areas of the southernmost South American Platform. The main outcrop areas of the RPC include the crystalline basement in the central to southwestern Uruguay (Dalla Salda et al. 1988), the Buenos Aires Complex of the Tandilia Belt in Argentina and the Taquarembó block of Brazil (Hartmann et al. 1999).

The rocks assigned to this craton are also on the Martín García Island (Ravizza 1984). This reinforces the hypothesis that the spider fauna found in the Island could be similar to that of the Brasilian region. The mygalomorph spider fauna of the island presents species distribution patterns resulting from vicariant events that gave rise to the remnants of the Río de la Plata craton. Consequently, this fauna exhibits a greater relationship with Uruguay and southern Brazil than the Mesopotamian region of Argentina (Ferretti et al. 2010, 2012, 2014).

The same applies to scorpions in hilly systems in Buenos Aires, in Uruguay and in southern Brazil (Maury 1995; Ojanguren-Affilastro 2005). With regard to the Saticidae on Martin Garcia Island, except *Aphirape flexa, Dendryphantes mordax, Euophrys saitiformi*s, *E. sutrix, Saitis variegatus* and *Trydarssus pantherinus*, the rest of the species are recorded in Brazil.

Numerous research has detailed the strong relationship between vegetation structure and the composition of spider communities (Wise 1993). Spider assemblages are highly influenced by variations in plant community structure and ecosystem dynamics such as disturbance, and abiotic factors such as soil and ambient humidity and temperature (Bonte et al. 2002). Vegetation provides varying types of sustrate or microhabitats that are differentially suitable for animal species. There is evidence that microhabitat selection is affected by the size or diversity of a community (Marshall and Rypstra 1999) as well as by food availability (Toft and Wise 1999). In addition, there is often a shift of habitat utilisation caused by changing requirements of the species due to seasonality, reproduction or life cycle (Berg and Bengtsson 2007).

Salticidae, in the stalkersguild, can be also found in several microhabitats especially during the day, frequently foraging on vegetation and litter (Wise 1993). Jumping spiders are extremely active with sunlight exposure; so, it is very common to see them in places with high sunlight radiation. *Trydarssus pantherinus, Agelista* sp. and *Dendryphantes mordax* showed a greater preference for habitat, as the first two were found in the SXF and the last in AXF. At the other end, *Chira gounellei* and *Coryphasia* sp. presented greater adaptability to different environmental conditions and/or a lower specificity in terms of microhabitats occupied. They were recorded in all habitats. *Aphirape flexa, Breda* cf. *variolosa, Gastromicans albopilosa, Lyssomanes pauper, Saitis variegatus, Semora napaea* and *Synemosyna aurantiaca* were found in all habitats except SA. *Bellota* sp., *Euophrys sutrix, Neonella* sp. and *Scoturius* n. sp. appeared in J, AXF and SXF, continuous environments and which are adjacent to each other. Jungle had the greatest abundance, followed by SF and SXF, which is expected in those environments that provide a lot of different microhabitats, prey availability, shelters, etc. However, the highest species richness was recorded in SXF, followed by AXF and J, in connection with the edge zones. These may affect the organisms by causing changes in abiotic conditions (Murcia 1995). Thus, the abundance, distribution and life cycles (Maelfait and De Keer 1990) of populations change together with the interactions between them. The biota itself plays a role in creating and maintaining the spatial heterogeneity of abiotic factors. For example, plants affect air and soil humidity and temperature, and intercept light and rainfall (Murcia 1995). Vegetation diversity is claimed to be higher in edge zones, and the vegetation with high structural and floral diversity tends to have higher invertebrate diversity (Meek et al. 2002). Sandy xerophilous forest edge areas are completely shared on one side with J and on the other with AXF, allowing species to exploit upcoming environments, and to register a greater number of species than the rest of the environments studied.

With regard to alpha diversity indices following the same trend, Chao 1 and Chao 2 are the estimators that are best adjusted. All similarity analysis showed that the least similar environment was SA. Also, Sorensen and Jaccard indexes represented the best environment relationship, establishing similarity groups: one that gathers the dry forests and another group that gathers J–SF. Similarity between environments could be explained by the type and structure of the vegetation.

In this study two genera and two species were new records for Argentina. In addition, three new species of jumping spider, as well as the discovery of the unknown male and female of two species were registered, which will describe in future taxonomic papers.

There is undeniable evidence that the environment is becoming more disturbed by human activity, whether it be from direct human development (He 2009), habitat fragmentation (Songer et al. 2009) or the introduction of invasive species (Levine and D'Antonio 2003). However, as expected for an island by having an urbanised centre and tourism activities there were no registrations of a large number of cosmopolitan spiders or of those with a large distribution range.

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Disclosure statement

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