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Spider (Araneae: Araneomorphae) diversity in Annaba Province, Northeastern Algeria

Diversidad de Arañas (Araneae: Araneomorphae) en la Provincia de Annaba, noreste de Argelia

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ABSTRACT

Spiders, as predatory arthropods, play essential roles in ecosystem equilibrium and serve as bioindicators. To contribute to the understanding of spider diversity in northeast Algeria (Annaba province), a survey of spider fauna was conducted in forest and urban sites over two consecutive years using the "hand collecting" method. A total of 879 adult spiders (681 females and 198 males) were identified, representing 25 families and 67 species. The salticid *Plexippus paykulli* (Audouin, 1826) was the most abundant species, with 127 specimens collected. The most abundant families were Salticidae and Araneidae, with counts of 171 and 139 individuals, respectively. The Shannon-Weaver index varied from 2.17 to 3.68 bits across the different sites, while evenness values ranged from 0.60 to 0.75. This study significantly expanded the known spider species for the Annaba province from 96 to 138.

Keywords: Arthropoda, Arachnida, North Africa, inventory, systematic.

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RESUMEN

Las arañas, como artrópodos depredadores, desempeñan roles esenciales en el equilibrio del ecosistema y actúan como bioindicadores. Para contribuir a la comprensión de la diversidad de arañas en el noreste de Argelia (provincia de Annaba), se realizó un estudio de la fauna de arañas en sitios forestales y urbanos durante dos años consecutivos utilizando el método de "recolección manual". Se identificaron un total de 879 arañas adultas (681 hembras y 198 machos), representando 25 familias y 67 especies. El salticido *Plexippus paykulli* (Audouin, 1826) fue la especie más abundante, con 127 especímenes recolectados. Las familias más abundantes fueron Salticidae y Araneidae, con 171 y 139 individuos, respectivamente. El índice de Shannon-Weaver varió de 2.17 a 3.68 bits en los diferentes sitios, mientras que los valores de equidad variaron de 0.60 a 0.75. Este estudio amplió significativamente las especies de arañas conocidas para la provincia de Annaba de 96 a 138.

Palabras clave: Artrópodos, Arácnidos, África del Norte, inventario, sistemática.

INTRODUCTION

Spiders are the largest order of arachnids (Sebastian and Peter, 2009), with over 50000 known species (World Spider Catalog [WSC] 2024). These arthropods are generalist predators, highly abundant and found in almost every ecosystem on the planet (Garrison, Rodriguez, Agnarsson, Coddington, Griswold, 2016). Spiders fulfill an important role in maintaining ecological balance (Misal Bendre, Pawar, Bhoite, Deshpande, 2019) by serving as biological regulators of pest populations (Sahoo Mishra, Seth, Murmu, Goud, 2022) and potentially acting as bio-indicators of habitat quality (Rodríguez-Artigas, Ballester, Corronca., 2016; Gómez, Lohmiller, Joern, 2016). The significant diversity and sensitivity to ecological changes make spiders ideal models for conservation studies (Cardoso and Morano, 2010).

Algeria is the largest country in Africa covering an extensive area of over 2 million km^2. It is marked by a rich ecosystem diversity (Beddek, 2017), ranging from coastal areas to mountainous regions and vast deserts. Within this ecological diversity, the region of Annaba, located in the northeast of the country, stands out as an area of interest. Characterized by the Edough Forest Massif, which is one of the most diversified areas in Algeria and a plant biodiversity hotspot within the Palearctic ecozone (Comes, 2004). It is home to a significant array of rare species with high biogeographical interest (Boulahbal, Zaanoune, Rouag, Boukheroufa, Sakraoui, R., Dadci, 2022). The Edough forests have been the focus of numerous studies on various faunal groups, such as Odonata (Samraoui and Alfarhan, 2015), Coleoptera (Hadiby Boukheroufa, Adjami, Djedda, Boussaha, 2022), Mammalia (Belbel, Boukheroufa, Benotmane, Sakraoui, Henada, 2022; Benotmane, Boukheroufa, Sakraoui, Sakraoui, Centeri, 2024), and Lepidoptera (Laref, Rezzag-Bedida, Boukheroufa, Sakraoui, Henada., 2022).

The present paper revolves around the study of the forest and urban spider fauna within Annaba province. Its purpose is to contribute to the enrichment and updating of information on the diversity of spiders in northeastern Algeria.

MATERIALS AND METHODS

Study Area

The coastal province of Annaba situated in eastern Algeria, is located approximately 600 km from the capital city of Algiers and covers an area of 1412 km (*In* Benotmane, 2024). The mountainous area covers 52% of the province's territory and is characterized by the Edough Mountain, where our forest study stations are situated. The Edough forests are dominated by the *Quercus suber* and *Quercus canariensis* species (Oularbi and Zeghiche, 2009). The climate of the province is Mediterranean-type, characterized by hot and dry summers as well as mild and humid winters (Dong, Leung, Lu, Song, 2021). This study investigated six distinct sites. The initial four are situated within the forested region of Edough. The fifth site is centrally located in Annaba, while the sixth site is positioned at Badji Mokhtar- Annaba University. Our study zone extends between longitudes 7°39' E and 7°46' E, and latitudes 36°56' N and 36°48' N (Figure 1).

Spider Sampling

Spider sampling was conducted using the hand-collecting method through active daytime searches, with two hours dedicated to each site. Specimens were collected along a 500-meter randomized transect using vials and tweezers. The sampling of forest spiders took place over a period of two years, from June 2021 to May 2023, with a frequency of two outings per month. Simultaneously, a monthly outing was conducted for sampling urban spiders, covering the period from August 2021 to July 2022. In the forest, we explored the ground, under stones, plants, tree trunks, and bark crevices. In the urban area, we examined buildings and gardens, focusing on vegetation, walls, holes, cracks, and ceilings. It is worth noting that the juvenile specimens collected were released back into their natural habitat.

Taxonomic Identification of Spiders

Specimens were conserved in 70° ethanol and subsequently determined in the laboratory using a Ceti Steddy stereo microscope. The identification process was conducted using several reference books: (Roberts, 1995,

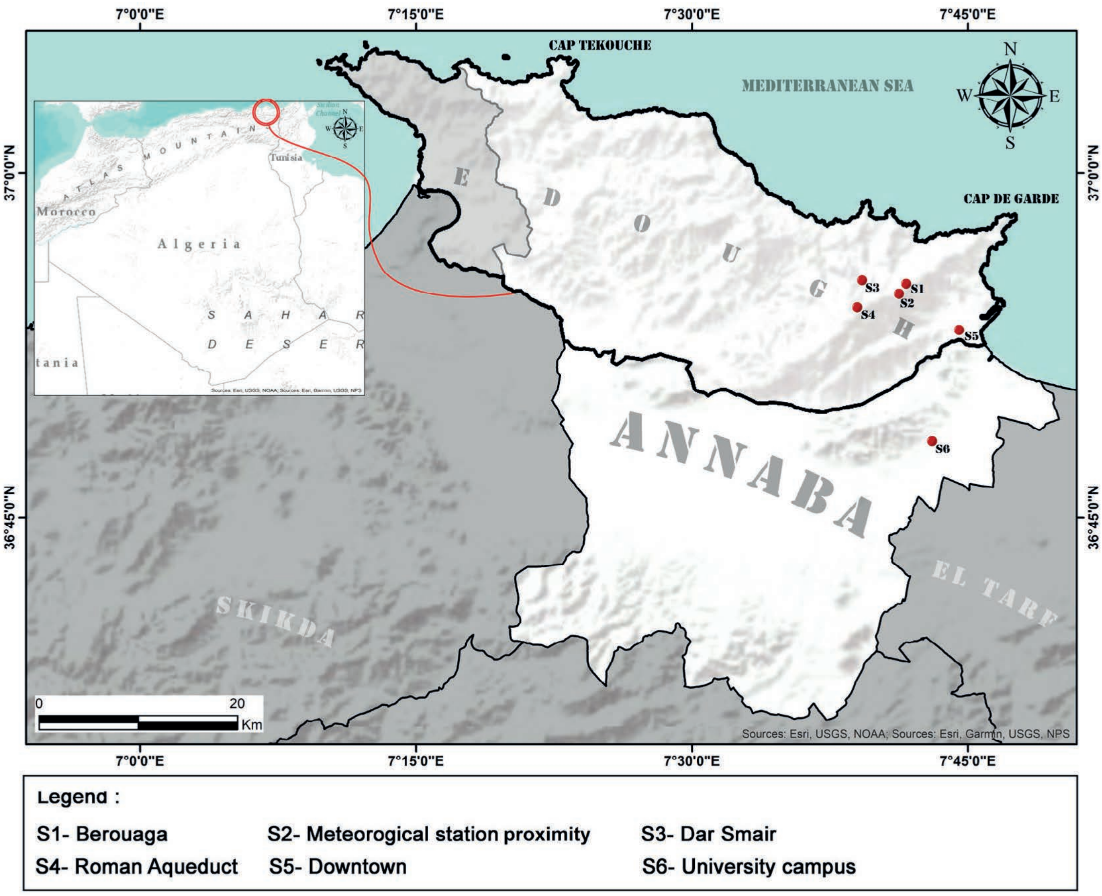

Figure 1. Location of the study sites (Annaba, Algeria).

1998; Jocqué and Dippenaar-Schoeman, 2006; Le Peru, 2011), along with "*Spiders of Europe*" website. The WSC (2024) is also used for species and author nomenclature.

Data Analysis

The diversity index of Shannon-Weaver (Shannon and Weaver, 1949) was calculated using the following formula:

$$H' = -\sum_{i=1}^{S} pi \log_2 pi$$

where $Pi = n/N$, n is the number of individuals of the i^{th} species and N the total number of individuals in the sample (DeJong, 1975). The evenness (E) was calculated as:

$$E = \frac{H'}{H'\,max}$$

where $H'max = \log_2 S$ and S is the species richness (Pielou, 1969). Factorial correspondence analysis (FCA) and Hierarchical Ascending Classification (HAC) were carried out using XLSTAT software (Trial version 2024).

RESULTS

In this study, only mature specimens were considered, leading to the identification of 879 spiders in total: 681 females (77.5%) and 198 (22.5%) males, encompassing 25 families and 67 species. The most abundant species were: *Plexippus paykulli* (Audouin, 1826) (n = 127; 14.4%) (Figure 6), *Linyphia tenuipalpis* Simon, 1884 (n = 111; 12.6%), *Zoropsis spinimana* (Dufour, 1820) and *Uroctea durandi* (Latreille, 1809) each account (n = 71; 8.1%).

Among the families collected, Salticidae (Blackwall, 1841) and Araneidae (Clerck, 1757) were the richest families with 14 and 9 species respectively. However, there were 14 families each represented by a single species (Table 1). Percentagally, the most abundant families were: Salticidae (19%), Araneidae (16%), Pholcidae (14%), and Linyphiidae (13%) with counts of 171, 139, 123, and 114 individuals, respectively. The remaining families were represented by fewer than 100 individuals each, with seven families represented by only one individual each (Figure 2).

As previously mentioned, these samples originate from two distinct environments (forested and urban). The forest area exhibited the highest count of individuals and species (N = 591; S = 44). On the other hand, the urban area showed the lowest count, with 288 individuals and 28 species. *Textrix caudata* L. Koch, 1872, *Argiope bruennichi* (Scopoli, 1772), *Argiope trifasciata* (Forsskål, 1775), *Pulchellodromus bistigma* (Simon, 1870) and *Plexippus paykulli* (Audouin, 1826) were the common species between the two zones.

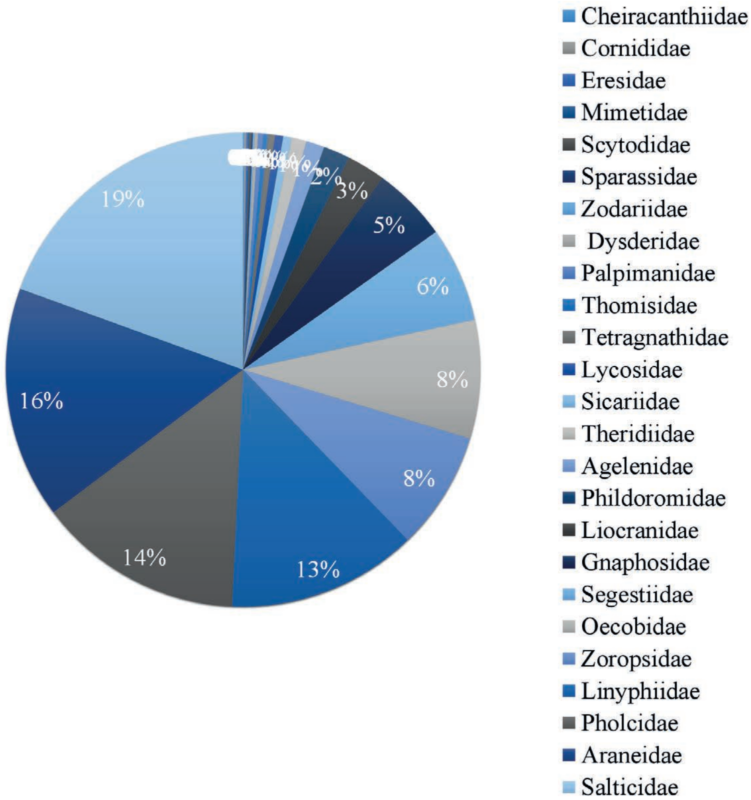

Figure 2. Relative abundance of spider families collected in Annaba province.

Table 1. Species list and abundance of spiders collected in Annaba province (F: forest area; U: urban area).

Family	Species	Code	F	U
Agelenidae	Agelenidae sp.	Sp1	1	0
	Lycosoides coarctata (Dufour, 1831)	Sp2	5	0
	Textrix caudata L. Koch, 1872	Sp3	2	3
Araneidae	Araneidae sp.	Sp4	1	0
	Araneus angulatus Clerck, 1757	Sp5	9	0
	Araneus pallidus (Olivier, 1789)	Sp6	60	0
	Argiope bruennichi (Scopoli, 1772)	Sp7	1	1
	Argiope lobata (Pallas, 1772)	Sp8	3	0
	Argiope trifasciata (Forsskål, 1775)	Sp9	2	1
	Cyrtophora citricola (Forsskål, 1775)	Sp10	0	31
	Leviellus kochi (Thorell, 1870)	Sp11	1	0
	Zilla diodia (Walckenaer, 1802)	Sp12	29	0
Cheiracanthiidae	*Cheiracanthium mildei* (L. Koch, 1864)	Sp13	0	1
Corinnidae	*Castianeira* sp	Sp14	1	0
Dysderidae	*Dysdera* sp	Sp15	1	0
	Harpactea sp	Sp16	1	0
Eresidae	*Stegodyphus dufouri* (Audouin, 1826)	Sp17	0	1
Gnaphosidae	*Drassodes lapidosus* (Walckenaer, 1802)	Sp18	1	0
	Heser nilicola (O. Pickard-Cambridge, 1874)	Sp19	6	0
	Nomisia aussereri (L. Koch, 1872)	Sp20	2	0
	Poecilochroa sp	Sp21	3	0
	Scotophaeus blackwalli (Thorell, 1871)	Sp22	8	0
	Scotophaeus scutulatus (L. Koch, 1866)	Sp23	0	4
	Scotophaeus validus (Lucas, 1846)	Sp24	20	0
	Urozelotes rusticus (L. Koch, 1872)	Sp25	0	1
Linyphiidae	*Frontinellina frutetorum* (C. L. Koch, 1835)	Sp26	3	0
	Linyphia tenuipalpis Simon, 1884	Sp27	111	0
Liocranidae	*Mesiotelus mauritanicus* Simon, 1909	Sp28	23	0
Lycosidae	Lycosidae sp 1	Sp29	1	0
	Lycosidae sp 2	Sp30	1	0
	Pardosa proxima (C. L. Koch, 1847)	Sp31	0	1
	Trochosa sp	Sp32	2	0
Mimetidae	*Mimetus laevigatus* (Keyserling, 1863)	Sp33	1	0
Oecobidae	*Uroctea durandi* (Latreille, 1809)	Sp34	71	0
Palpimanidae	*Palpimanus gibbulus* (Dufour, 1820)	Sp35	0	3
Philodromidae	*Philodromus praedatus* O. Pickard- Cambridge, 1871	Sp36	3	0
	Pulchellodromus bistigma (Simon, 1870)	Sp37	7	5
	Tibellus sp	Sp38	0	1
Pholcidae	*Holocnemus pluchei* (Scopoli, 1763)	Sp39	0	68
	Pholcus phalangioides (Fuesslin, 1775)	Sp40	0	53
	Spermophora senoculata (Dugès, 1836)	Sp41	0	1
	Spermophorides elevata (Simon, 1873)	Sp42	0	1
Salticidae	*Aelurillus* sp	Sp43	4	0
	Cyrba algerina (Lucas, 1846)	Sp44	0	1
	Euophrys sp	Sp45	2	0
	Hasarius adansoni (Audouin, 1826)	Sp46	0	2
	Icius hamatus (C. L. Koch, 1846)	Sp47	1	0
	Menemerus semilimbatus (Hahn, 1829)	Sp48	0	17
	Philaeus chrysops (Poda, 1761)	Sp49	0	1
	Phlegra bresnieri (Lucas, 1846)	Sp50	0	1
	Plexippus paykulli (Audouin, 1826)	Sp51	54	73
	Pseudeuophrys erratica (Walckenaer, 1826)	Sp52	8	0
	Salticidae sp	Sp53	1	0
	Salticus confusus Lucas, 1846	Sp54	1	0
	Salticus scenicus (Clerck, 1757)	Sp55	4	0
	Thyene imperialis (Rossi, 1846)	Sp56	0	1
Scytodidae	*Scytodes thoracica* (Latreille, 1802)	Sp57	0	1
Segestriidae	*Segestria florentina* (Rossi, 1790)	Sp58	15	0
	Segestria senoculata (Linnaeus, 1758)	Sp59	42	0
Sicariidae	*Loxosceles rufescens* (Dufour, 1820)	Sp60	0	5
Sparassidae	*Micrommata ligurina* (C. L. Koch, 1845)	Sp61	0	1
Tetragnathidae	*Metellina merianae* (Scopoli, 1763)	Sp62	4	0
Theridiidae	*Nesticodes rufipes* (Lucas, 1846)	Sp63	0	2
	Steatoda triangulosa (Walckenaer, 1802)	Sp64	0	7
Thomisidae	*Xysticus cristatus* (Clerck, 1757)	Sp65	3	0
Zodaridae	*Zodarion* sp	Sp66	1	0
Zoropsidae	*Zoropsis spinimana* (Dufour, 1820)	Sp67	71	0

Spider Guilds Composition

In total eight guilds were identified: ground hunters, ambush hunters, sensing web weavers, space web weavers, orb web weavers, sheet web weavers, specialists, and other hunters. The weaver spider guilds represented significantly higher abundance at 68.2%, compared to the hunter spider guilds at 31.7%.

In the forest environment, the sheet web weavers constituted the predominant guild (32.6%), succeeded by the sensing web weavers (21.6%), while the ground hunters exhibited the greatest species diversity (25%). Conversely, within the urban zone, the space web weavers emerged as the dominant guild (45.8%), followed by the other hunters (36.1%), with the latter demonstrating the highest species richness (39.2%) (Figure 3).

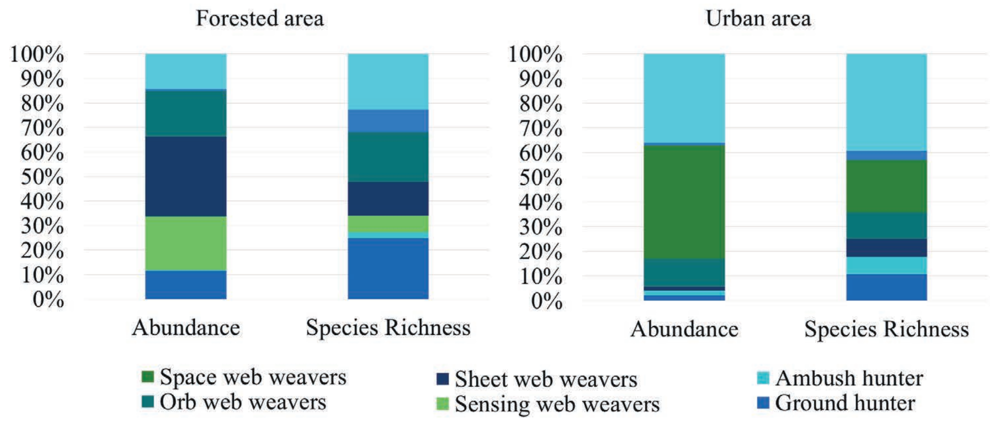

Figure 3. Spider guild abundance and richness. Percentage of species and individuals per guild in each studied zone.

Abundance and Diversity Parameters

The abundances of spiders recorded range from 90 to 198, with Site 4 having the highest abundance overall. Among urban sites, Site 5 has a relatively high abundance comparable to the forest sites. The species richness is notably higher in the forest sites, particularly in Site 4 (S = 29). The Shannon Index is higher in Sites 4 and 3 (3.68 bits and 3.38 bits, respectively), indicating greater diversity. The evenness values range between 0.60 and 0.75, suggesting a slight imbalance in the spider population, characterized by an unequal distribution with some species showing a dominance over others (Table 2).

Table 2. Abundance and diversity parameters per site.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Abundance	127	90	176	198	176	112
Species richness	12	15	22	29	17	16
Diversity (bits)	2.17	2.74	3.38	3.68	2.74	2.77
Evenness	0.60	0.70	0.75	0.75	0.67	0.69

Hierarchical Ascending Classification (HAC)

The dendrogram clearly delineates the separation between forest and urban sites, indicating distinct species compositions in the two habitat types. The forest sites cluster into two subgroups [C1: (S1 and S2) ; C2: (S3 and S4)], whereas the urban sites form a distinct group, C3: (S5 and S6). The minimal dissimilarity observed between S1 and S2, as well as between S3 and S4, indicates a high degree of species composition similarity within these forest subgroups. The urban sites S5 and S6 exhibit similarities between them while distinctly differing from the forest sites (Figure 4).

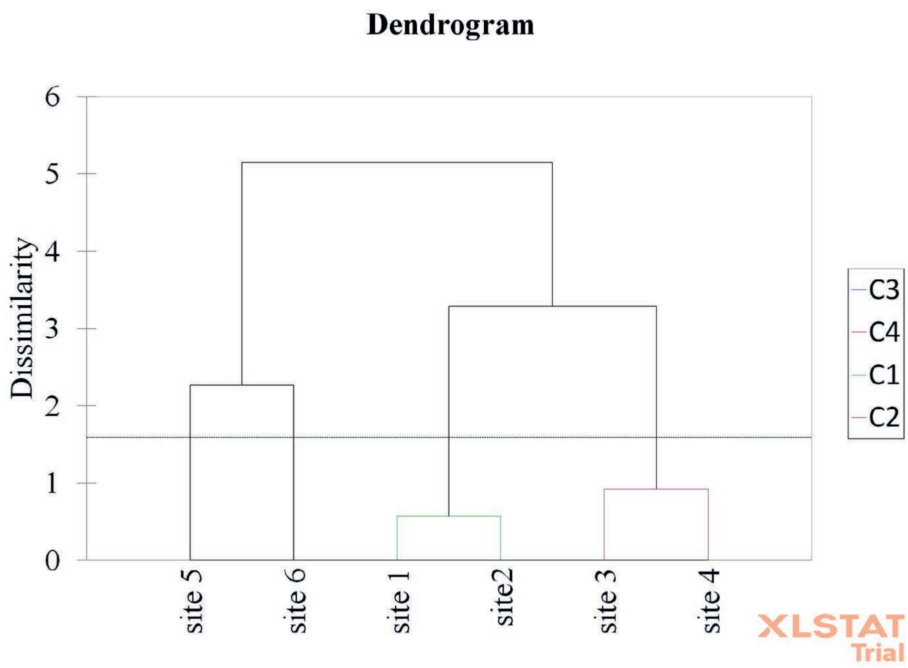

Figure 4. Hierarchical ascending classification dendrogram, illustrating the dissimilarity among study sites based on the specific spider composition.

Factorial Correspondence Analysis (FCA)

The axes F1 and F2 account for 69.53% of the total inertia. The FCA reveals that forest sites exhibit a higher and more clustered species diversity, while urban sites, located in the right half of the plot, show a different set of species, indicating the influence of habitat type on spider distribution. The placement of species like Sp3, Sp9, and Sp7 (*Textrix caudata*, *Argiope trifasciata* and *Argiope bruennichi*, respectively) along the F1 axis indicates that these species do not exhibit a strong association with a single site or a tight cluster of sites. *Plexippus paykulli* (Sp51), the most abundant species is positioned further from the cluster of forest sites, suggesting it is likely more prevalent in urban environments (Figure 5).

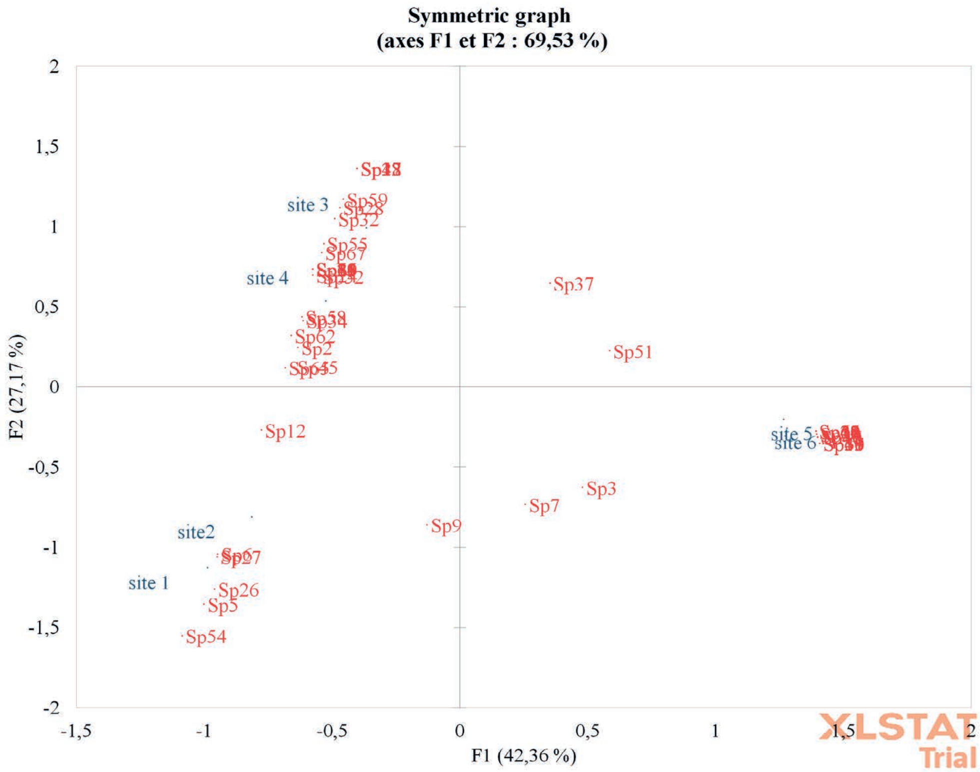

Figure 5. Factorial correspondence analysis graph. Ordination of the spider species collected across the six sites along the axes 1 and 2.

DISCUSSION

The systematic study of spiders has revealed the presence of 67 species, significantly contributing to the updating of the faunal list of spiders in Annaba Province. Initially, the known number of species documented for this province stood at 96 (Benhacene et al., 2023). Subsequently, this figure has risen from 96 to 138 species, constituting a notable increase of 43.7% relative to the previous enumeration. Notably, among the 67 species reported within this locale, 12 species were previously mentioned, while 42 represent novel additions.

In the present study, the highest abundance of spiders (591 individuals) was reported in the forested area, which can be attributed to the substantial sampling effort deployed in this zone. The high number of sampled sites and the extended sampling duration had a significant impact on the number of spider individuals collected. The highest species richness (44 species) was also recorded in the forest environment. This can be explained by the forest's abundant resources with the wide range of habitats and ecological niches that various spider species can exploit. Samu, Sunderland, Szinetár, (1999) highlighted that spider abundance and diversity are positively correlated with environmental diversity across various spatial scales. Dajoz (2007), Khandekar and Srivastava (2014) further emphasized that forests host a significant majority of terrestrial species globally, surpassing other ecosystems.

Spider assemblages are controlled by environmental factors such as humidity, temperature, and habitat structure, as well as biotic interactions including competition, intraguild predation, and predation (Wise, 1993; Samu et al., 1999; Gunnarson, 2007; Ziesche and Roth, 2008; Gan, Liu, Yang, Li, Lei, 2015; Petcharad et al., 2016). In forests, spider composition is strongly influenced by the structure and diversity of vegetation (Cernecká, Michalko, Krištín, 2017; Lafage, Djoudi, Perrin, Gallet, Pétillon, 2018; Li et al., 2018). In our research, sheet web weavers emerged as the dominant guild in forest sites, and mostly represented by spiders from the Linyphiidae family. Indeed, these spiders have been frequently observed in forest environments worldwide, often with remarkable abundance (Schulz and Schmidt, 1998; Buddle, 2004; Seyfulina and Bakker, 2007). The complex and multi-layered structure of forest vegetation offers plentiful optimal sites for web construction, promoting the presence of sheet web weavers. Regarding the urban sites, the space web weavers were the dominant guild, mainly represented by the Pholcidae family. These spiders are frequently reported in urban areas near humans (Huber, 2005; Vetter, 2011). The availability of nesting sites, diversity of attachment points, and abundance of prey in urban areas all contribute to their high abundance in these environments. Human dwelling, in particular, attract numerous insects, creating protected, food-rich spots.

It is noteworthy that our study recorded a total abundance of 879 individuals belonging to 67 species. In comparison, Touchi Kherbouche-Abrous, Saadi, Beladjal, (2018) sampled 1215 spiders representing 48 species in the Zéralda pine forests, while Mansouri et al., (2019) reported 1476 specimens belonging to 68 species in the Chréa National Park. In the Mediterranean region, significant records have been documented across different forests. For instance, Cardoso, Scharff, Gaspar, Henriques, Carvalho, (2008) collected 21748 spiders representing 204 spider species in a mixed English oak and Pyrenean oak forest in Peneda-Gerês National Park, northern Portugal. Similarly, Malumbres-Olarte et al., (2020) collected 20551 specimens belonging to 375 species in national parks across the Iberian Peninsula.

In the present study, 25 families were identified, representing 49% of the families documented at the national scale (Benhacene et al., 2023). The family Salticidae is the most recorded in Annaba, with 171 individuals. Indeed, these spiders, commonly known as jumping spiders, are distributed worldwide (Bodner and Maddison, 2012). Their physiological and behavioral traits enable them to thrive in a wide variety of habitats. They can be found in grasslands, forests, deserts, and even in areas with high human activity, such as residential zones (Jasmi and Jarna, 2021).

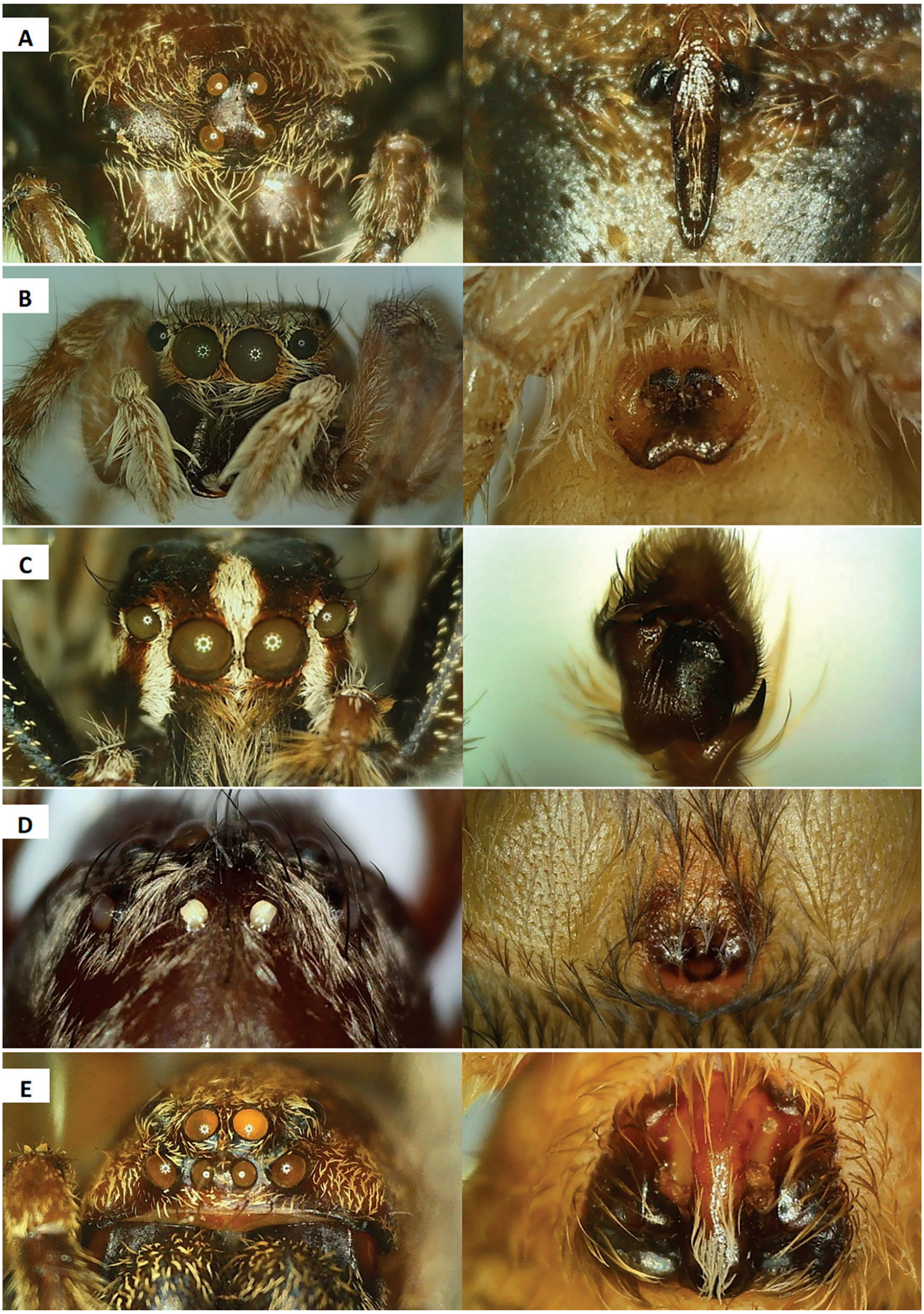

Figure 6. Digital photographs of some collected species, focusing on their eyes and genitalia (A: *Araneus angulatus*, B: *Menemerus semilimbatus*, C: *Plexippus paykulli*, D: *Scotophaeus blackwalli*, E: *Zoropsis spinimana*).

Molinari (1989) defined the evenness as the degree to which the abundances are equal among the species present in a sample or community. In the case of our study, the evenness values range from 0.60 to 0.75, indicating a slight imbalance in the spider population. This suggests an uneven distribution, mainly due to the presence of several dominant species across the different sites: *Linyphia tenuipalpis* ranked first in sites 1 and 2, *Zoropsis spinimana* in sites 3 and 4, *Holocnemus pluchei* in site 5, and *Cyrtophora citricola* in site 6.

The FCA shows that forest sites have higher and more clustered species diversity than urban sites, which exhibit a distinct species composition, suggesting the influence of habitat type on spider distribution. Indeed, each spider species has evolved to adapt to a specific set of environmental conditions. Several research studies have highlighted that spider habitat selection is heavily influenced by a range of factors: prey availability and diversity (Lubin et al., 1993; Horváth et al., 2005), temperature and humidity (Li and Jackson 1999; Voss et al., 2007), and structural complexity of the habitat (Halaj et al., 2000; Rinaldi and Trinca, 2008). Concerning *Plexippus paykulli*, this jumping spider species has been documented in various environments such us shoreline vegetation, casuarina forests, rainforests, and human habitations (Zabka and Nentwig, 2000). While this species inhabits plants, it is also found on walls and other man-made structures (Seyfulina et al., 2020). Pupin and Brescovit (2023) suggested that it is generally associated with human dwellings and buildings.

PARTICIPATION

RB: conceptualization, data curation, formal analysis, investigation, writing (original draft, review and editing). YA: conceptualization, methodology, project administration, supervision, validation, writing (review and editing). KHB: investigation, resources, writing (original draft). RH: resources, software. MLO: conceptualization, supervision, validation, writing (review and editing).

CONFLICTS OF INTEREST

The authors state that there are no potential conflicts of interest

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