Ground-living spider assemblages from Mediterranean habitats under different management conditions

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Abstract. Ground-living spiders of different habitats in the Cabañeros National Park, central Spain, each under different management conditions, were studied to characterize their community richness and composition. Five different habitats were selected: Mediterranean forest, abandoned pine plantations and three kinds of *dehesas* or meadows (differing in their understory management). In three sampling periods, during two springs and one in fall (2001–2002), a total of 1,152 pitfall traps were deployed in five different habitats. A total of 3,801 adult spiders, representing 105 species from 24 families were collected, among which 13 are considered endemic for the Iberian Peninsula. Correspondence analysis and indicator species analysis showed that spider richness and assemblages differed considerably among the different habitats. The scrub *dehesa* had the highest ground-living spider richness. Twenty-three indicator species were identified for the different habitats, of which four are considered endemic for the Iberian Peninsula. Gnaphosidae have a high potential as indicators of habitat quality.

Keywords: Araneae, *dehesa*, endemic, Iberian Peninsula, indicator species

Ground-living spider (Araneae) assemblages are influenced by environmental heterogeneity and land use (Grill et al. 2005). Spiders are ubiquitous predators in terrestrial ecosystems and generalist feeders that primarily attack insects; therefore, these arthropods play a main role in terrestrial population control (Wise 1993).

The Mediterranean region exhibits high biological richness, apparently due to its diverse evolutionary pathways and in situ speciation processes (Blondel & Aronson 1999). This region has had to bear the brunt of intensive human activity: woodcutting, land clearing for cultivation and settlement, grazing, fire, and in recent years, pollution, pesticides and other biocide applications. These activities have all left their footprints on the ever-changing Mediterranean landscape (Perevolotsky & Seligman 1998). They have led to a characteristic landscape with a strong cultural component, resulting in a "successful" integrated, semi-natural system that has been maintained through time (Pineda 2001). The ensuing heterogeneous landscape has elements of diverse ecological maturity, ranging from forests to crops (Médail & Quézel 1999; Ramírez-Sanz et al. 2000; Schmitz et al. 2003). Long-term effects of land use by human communities and the impact of their livestock on the vegetation and fauna have been emphasized by Blondel and Aronson (1999). The Iberian Peninsula contains 1,500,000–3,400,000 ha of wooded *dehesa*, mainly in the southwest. Among exploitation systems, the *dehesa*, derived from the original Mediterranean forest landscape use (Díaz et al. 2003a), has been exploited throughout history as a diverse resource, providing not only pasture for livestock but also building material, fuel, food, spices, and medicines (Perevolotsky & Seligman 1998). In central and southwestern Spain, the *dehesa* is an ancient wood-pasture with oak *Quercus* spp. trees, a mixture of cereal cultivation, open grasslands and Mediterranean scrub beneath the tree canopy (Díaz & Pulido 1995). Agricultural and pastoral uses affect the structure and diversity of the *dehesa* (Pineda & Peco 1987; Joffre et al. 1988; Díaz et al. 2003a).

Mediterranean forests, together with the *dehesas*, have high biodiversity levels and were consequently included as protected habitats on the EU Habitat Directive (92/43/CEE). This is true for several taxa across the range of environmental conditions and geographical scales (Díaz & Pulido 1995; Jiménez-Valverde et al. 2004).

World conservation priorities are based on biodiversity studies focused on relatively well known groups of organisms, such as vascular plants and vertebrates: mammals, birds, reptiles and amphibians (Myers et al. 2000). However, fewer systematic and biogeographical data are available for hyperdiverse" groups such as spiders (Colwell & Coddington 1994), but which nevertheless need to be included in conservation policies (Kremen et al. 1993). Taking into consideration the lack of proper systematic surveys from many regions, Coddington & Levi (1991) estimate that 25–75% of the spider species are yet to be discovered. Within this range Melic (2001) estimates that ca 25% of spiders in the Iberian Peninsula are not yet described.

Spiders react mainly to habitat heterogeneity and land-use type, their richness is mainly determined by humidity and vegetation structure, reflecting the differing hunting strategies of ground-living and web-building spiders (Grill et al. 2005). Significant declines in spider and other arthropod diversity and abundance occur with increasing logging and decreasing herb cover (Willett 2001). A well-known local scale relationship between spider diversity and habitat structure suggests that spiders are a suitable group to test how communities change under different management practices and disturbance regimes (Uetz 1990).

The present study was undertaken within the pan-European project BIOASSESS Biodiversity Assessment Tools" (http://www.nbu.ac.uk/bioassess/), which is aimed to develop a set of ecological indicators according to a land-use disturbance
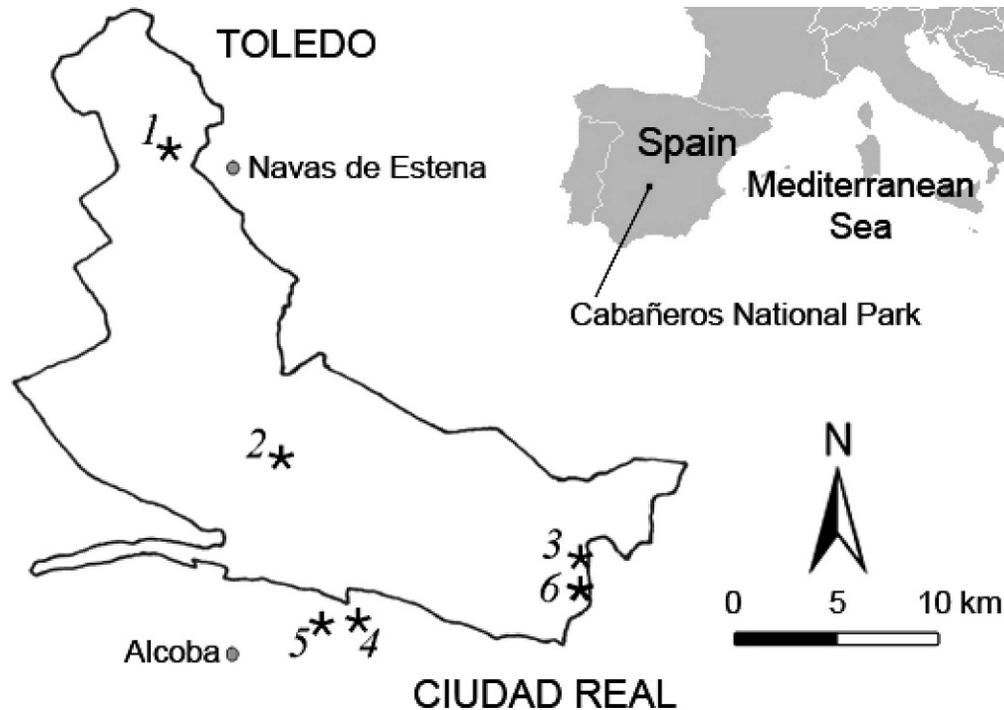
Figure 1.—Map of land units from BioAssess Project in the National Park Cabañeros, Spain.

gradient, with a significant increase of open landscapes (e.g., pastures and arable crops) in comparison to an old-growth woodland, including groups such as vascular plants (Fédoroff et al. 2005), lichens (Bergamini et al 2005), carabid beetles (Silva et al. 2008) and colembollans (Sousa et al. 2004, 2006; Ponge et al. 2003, 2006). This work aims to describe and compare the richness and species composition of ground-living spiders in several habitats of the Cabañeros National Park under different management conditions. Indicator species for each habitat are identified as well.

METHODS

Study area.—The study area was located in Cabañeros National Park, between northwestern Ciudad Real and southeastern Toledo provinces (39°23′47″N, 04°29′14″W of Spain and in surrounding private properties. The Park, situated in the "Montes de Toledo", is an area with typical Mediterranean forest in the center of the Iberian Peninsula, bordered by the Estena and Bullaque rivers (Fig. 1). Altitudes range from 620 to 1448 m above sea level, giving it a Mesomediterranean bioclimatic stage, with a dry to subhumid tendency (mixed oak forests of *Quercus pyrenaica*, *Q. suber*, and *Q. ilex* ssp. *ballota*), characterized by dry and hot summers. The Park contains *dehesa*s, savannah-like landscapes of grassland and scattered trees, mainly *Quercus* ssp. Average annual temperature and precipitation are 14.9°C and 607 mm, respectively. The area (41,000 ha) is highly representative of the vegetation, fauna and land uses in the southern high plain of the Iberian Peninsula.

In each European country participating in the pan-European project BIOASSESS, six Land Units, one square kilometer each, were intuitively selected on the basis of regional knowledge and aerial photographs, taking into account the distribution of forested areas, meadows and agricultural crops (for further information see Sousa et al. 2006). In this study five habitats were clearly identified and selected according to their different management practices along a gradient: from forest habitat units to agriculture-dominated ones (Table 1). Forest habitats differed in the heterogeneity of strata and in the composition of dominant trees and understory vegetation, whereas *dehesas* differed in grass layers and scrub density. The following habitat types were surveyed:

1. *Mediterranean forest (MF)*: A shaded slope located inside the Park extending 5 km² along the Estena River. Soil shows poorly developed horizons with superficial litter. This habitat is characterized by a mosaic of evergreen oaks, holly oaks (*Q. ilex* ssp. *ballota*), corks (*Q. suber*); deciduous oaks (*Q. faginea* ssp. *broteroi* and *Q. pyrenaica*) and strawberry trees (*Arbutus unedo*). Its understory is heterogeneous, composed mainly of sclerophyllous shrubs such as *Cistus ladanifer*, *Erica arborea*, *E. scoparia*, and *Phyllirea angustifolia*. This forest was probably used in the past for timber and charcoal production. Currently, the area is used for the extraction of wood by pollarding and coppicing (around 0.6 m³/ha/yr). Cork extraction is limited to the largest individuals every 10 yr. Scrub removal is sometimes done for fire prevention. Goat grazing is allowed 100 days/yr, with an animal density lower than one goat per hectare.

2. *Old-pine plantation (OP)*: a 40-yr-old *Pinus pinaster* forest practically undisturbed (no commercial exploitation) for the last 15 yr that extends over 48 km² inside the Park. Its understory is composed of common shrub species of the Mediterranean woodland: *E. arborea*, *C. laurifolius*, *C. ladanifer*, and *Lavandula stoechas*. Com-

Table 1.—Characteristics of the five habitats and number of sampling plots used for ground-living spiders sampling.

| | Sampled area (ha) | Land units[a] | | | | | | Habitat characteristics | | | | |
		1	2	3	4	5	6	Vegetational layers[b]	Trees	Scrub	Grass	Management
Mediterranean forest	100	36						3	Abundant	Medium	Medium	Protected area
Old-pine plantation	100		42					3	Abundant	Few	Few	Protected area, without exploitation
Scrub *dehesa*	144			21	10	14	7	3	Medium	Abundant	Few	Protected area, lightly grazed
Grazed *dehesa*	144			8	9	16	14	2	Few-scattered	Absent	Abundant	Extensive grazing
Cultivated *dehesa*	112			8	17	11	12	1[c] or 2	Few-scattered	Absent	Absent or crop	Agricultural traditional land

[a] Land Units from Bioassess Project
[b] number of strata (trees, scrub or grass) presented in each habitat
[c] absence of cultivation or ploughing.

mon forest management practices consist of low-shrub removal and firebreak areas.

3. *Scrub dehesa (SD)*: These are lightly grazed habitats of typical Mediterranean scrublands and correspond to 24% of the total area under study (Jiménez-Valverde et al. 2004). They are Open forests consist of sparse holly oak and *Q. faginea* trees of medium height with a dense and diverse understory composed mainly of *C. ladanifer*, *A. unedo*, *Erica* spp., and *P. angustifolia*. they have abundant litter and soils, with a well-developed A-horizon.

4. *Grazed dehesa (GD)*: These are pastures or grassland habitats with low holly oak density, whose open habitats are grazed by domestic (from farms) and wild herbivores (in the Park); they make up 24% of the total area under study (Jiménez-Valverde et al. 2004). The coverage is characterized by a large area of short grass at ground level and a low area of shrubs. The area is also used for cereal cultivation and cork removal.

5. *Cultivated dehesa (CD)*: These are located in privately owned farms in the neighborhood of the Park. These homogeneous habitats, characterized by large areas of bare ground, have very scattered trees and are used intensely for arable crops. Cereal shifting cultivation is a common agricultural management practise, and it corresponds to 18% of the total area under study (Jiménez-Valverde et al. 2004). Ploughing is carried out yearly in late autumn and early spring, but sowing is performed every two years.

Sampling method.—Ground-living spiders were sampled in each Land Unit in which a grid of 16 sampling plots was established, all sampling points 200 m apart. Ground-living spiders were sampled from each sampling point using four unbaited pitfall traps (8 cm diameter × 10.5 cm depth) placed in a 2 × 2 quadrant, each pitfall 4 m apart (Silva et al. 2008). Traps were partly filled with propylene glycol (20%), and large stones were placed above them to minimize both flooding and damage from wild animals.

There were three sampling periods: May–June and October–December 2001, with 67 sampling plots each, and April–June 2002, with 91 sampling plots. During these periods 288 sampling plots were placed, of which 225 were recovered. Sampling periods were established based on the reported times of maximum abundance of adult spiders in Spain (Barrientos 1985), For short-term sampling programs, a period from the end of May to early June is recommended for the Iberian Peninsula (Cardoso et al. 2007) and other Mediterranean ecosystems (Chatzaki et al. 1998). The spiders collected were identified using a family level key (Barrientos & Ferrández 1985) and several papers for identification at the genus and species level (see Barriga et al. 2006) and deposited in the collection of the Museo Nacional de Ciencias Naturales de Madrid (MNCN). Most of the specimens (87%) were identified to the species level, 10.5% were identified to genera level and 2% were identified only to family level. Species richness is considered as one of the paramount parameters, useful and easy to interpret, to assess the biological diversity of a particular locality (Magurran 1989).

To know if our effort sufficed to provide a thorough representation of the spider community we used EstimateS Version 8.0 (Colwell 2001) to calculate accumulation curves of observed species richness using several different estimators (Chao 1, Chao 2 and second order Jackknife). Inventory sampling completeness, defined as the percentage of species estimated to exist in the sampling plots that are actually observed, was calculated using Chao 1 estimator (Cardoso et al. 2009). Accumulation curves have been performed in STATISTICA 6 (StatSoft, Inc. 1997), using the Clench equation.

Statistical analysis.—A correspondence analysis (CA) was performed with the initial data matrix of species (variables) and sampling plots (occurrences) (Benzecri 1973) to study the relationship between the new synthetic variables (ordination analysis axis coordinates with the higher variance absorption) and the factor habitat (five levels). Species with an occurrence below 10% of the total collection (Norris 1995) were neglected and not used for the analysis, meaning that only species present in more than 22 sampling plots were used. In order to detect the species of the outmost extremes of the gradients with a good representation of quality in the first and second axes, we selected those that had highest values of absolute contributions and relative contributions (Bordons et al. 2004).

Table 2.—Estimates of total ground-living spiders and those endemic to the Iberian Peninsula for each habitat.

	MF	OP	SD	GD	CD
Richness of species	46	28	69	55	45
Abundance average	307	714	423	513	380
Endemics	12 (4)	3	14 (2)	10 (1)	5
Singletons	18 (39%)	8 (11%)	29 (42%)	20 (36%)	17 (38%)
Doubletons	6 (13%)	1 (3%)	8 (12%)	9 (16%)	7 (15%)
Chao1	67.86	42.00	113.11	75.00	63.00
Chao2	67.25	41.67	112.24	74.60	62.65
Jackknife2	75.00	42.50	116.79	86.29	72.37
Completeness[a]	68%	66%	61%	73%	71%

( ) = exclusive to each habitat.

[a] = percentage of species estimated to exist in the sampling plots that are actually observed.

We performed two separate one-way ANOVAs using the scores obtained for each sampling plot in the first two axes as dependent variables and habitat as the independent factor.

To analyse the effect of factor habitat on the richness found in each sampling plot, a one-way ANOVA was performed. We used a post-hoc LSD test to detect differences between groups and subsequently applied a multiple test significance correction based on Benjamini & Hochberg's (1995) False Discovery Rate (FDR) method. The FDR method was chosen because it is less restrictive and has stronger inference properties than conventional methods (García 2004). A graphic representation of total richness found in each habitat (total and by sampling season) was also generated.

Indicator Species Analysis (INDVAL analysis: Dufrêne & Legendre 1997) was used to detect the characteristic species of each habitat. A Monte Carlo permutation test with 9999 permutations was carried out to test the significance for each indicator value (I.V.). Statistical analyses and calculations were performed on PC-ORD 4.0 (McCune & Mefford 1999) and STATISTICA 6 (StatSoft, Inc. 1997) software.
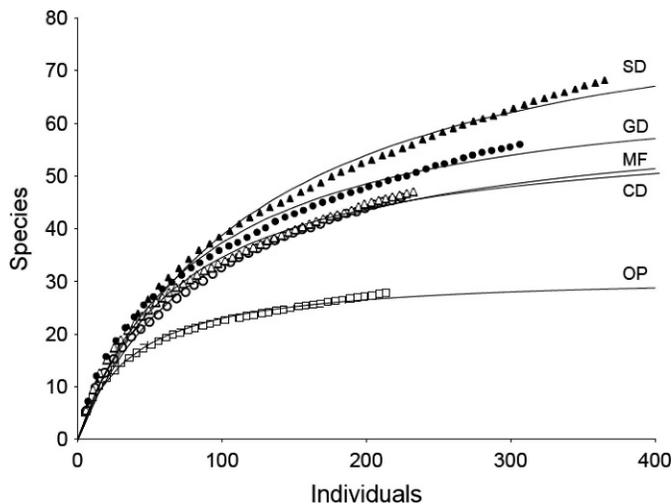

Figure 2.—Randomized accumulation curve for the five habitats; ○ Mediterranean forest (MF), □ Old-pine plantation (OP), ▲ Shrubby *dehesa* (SD), ● Grazed *dehesa* (GD), △ Cultivated *dehesa* (CD). Lines correspond to Clench equation.

RESULTS

Specimens were found in each of the 225 sampling plots. A total of 3,801 adult ground-living spiders were collected, representing 105 species and 24 families (see Appendix 1). The Gnaphosidae had the largest species representation (25 species), followed by Salticidae (13 species) and Linyphiidae (11 species). Thirteen species are cited in the Iberian Peninsula Endemic spider list (Melic 2001). The species richness and results of species richness estimators for each habitat are shown in Table 2. Species accumulation curves for each habitat indicate that species richness has not yet reached its maximum for any of the habitats (Fig. 2). The highest completeness value (73%) was found for GD and the lowest for SD (61%).

The non-parametric estimators indicate that species richness varies from 66% to 67.2% in the OP, from 68% to 68.4% in the MF, from 61% to 61.5% in the SD, from 73% to 73.7% in the GD, and from 71% to 71.8% in the CD (Table 2). Thus, the exhaustiveness of sampling in each of the five habitats is similar, so that abundances and species richness are comparable among habitats.

The highest richness and number of endemic species were found for SD (69 species, 14 endemic) with an estimate of 116.79 species (second-order Jackknife, Table 2). The lowest richness was found for OP (28 species, 3 endemic) with an estimate of 42.5 species (second-order Jackknife). Species richness dropped in the autumn. The forest habitats, MF and OP, showed minor differences in species richness between seasons, while the *dehesa*-type habitats (SD, GD and CD) showed the largest seasonal differences in species richness (Fig. 3). During spring, species presence was consistently above 80% of the total species sampled, even increasing to values over 90% in the *dehesas*. Few species were collected exclusively during autumn. *Xysticus robustus* was only collected in an open habitat (GD), and *Tegenaria atrica*, *Harpactocrates globifer*, *Drassodes fugax* and *Microlinyphia impigra* were collected in habitats with soils protected by several litter and vegetation layers (MF and OP).

In the CA performed on a data set comprising only the 20 most common species (those present in at least 10% of the sampling plots), the total inertia was 42%, with 14.9% and 11.7% for the first and second axes (Fig. 4). Using the sampling plot scores of the first axis, habitats differed significantly (one-way ANOVA, $F_{4, 215} = 88.3$, $P < 0.001$). No significant difference was found among habitats using
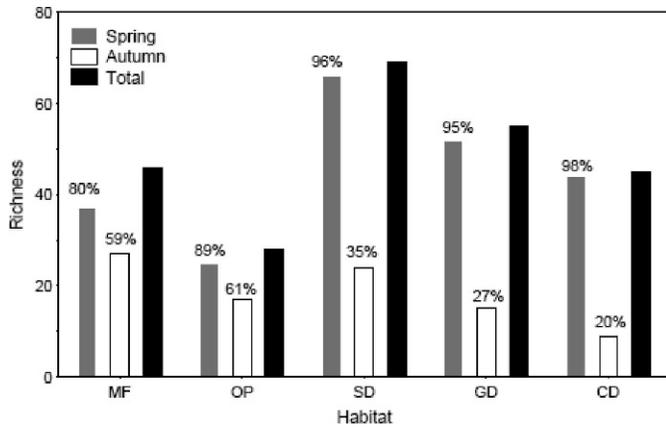
Figure 3.—Species richness of ground-living spiders during the course of the season in the different habitats. MF = Mediterranean forest, OP = Old-pine plantation, SD = Shrubby *dehesa*, GD = Grazed *dehesa*, CD = Cultivated *dehesa*. The relative proportions refer to each season with respect to the total richnness in each habitat.

Figure 5.—Comparison of mean species richness in each habitat. Different lower case letters indicate significant difference. Whiskers denote 95% confidence intervals. Note: ANOVA was performed on logarithmically transformed species richness values.

scores of the second axis (ANOVA, $P > 0.05$). Post hoc tests showed significant differences among all habitats except for GD and CD. This ordination analysis showed a clear relationship between the first gradient and the habitat factor. Sampling plots corresponding to the OP habitat are clearly placed on the negative side of axis 1, while sampling plots from the CD habitat all fall furthest to the right. *Phrurolithus festivus* represents the negative extreme of the first CA axis, and *Nomisia exornata* and *Alopecosa albofasciata* account for the positive extreme. The second axis, without marked polarity ordination results, is influenced by the presence of *Zelotes aeneus* on the positive side. *Z. aeneus* and *Tegenaria feminea* were the only species found in all habitat types.

Habitat also had a significant effect on the richness of sampling plots ($F_{4, 91} = 5.3$, $P < 0.001$; Fig. 5). Post hoc analysis showed that GD habitat has significantly higher richness (13.1 species) than OP and CD (9.4 and 8.6 species, respectively), but is similar to SD and MF (11.7 and 11.6 species, respectively).

INDVAL analysis revealed significant differences in spider assemblages among the five habitats (Table 3). All habitats included significant indicator species. OP, GD and MF had the highest numbers of indicator species (7, 5 and 5 species, respectively). The highest indicator value (I.V. = 55) corresponded to *Harpactea* sp. n. in MF. *Parachtes loboi* (I.V. = 51) was the most representative species for OP and *Nomisia exornata* for GD (I.V. = 50). The lowest number of indicator species was found for CD and SD (3 and 2 species, respectively) with I.V. < 50. Some of the indicator species are Iberian endemics, such as *Tegenaria feminea* in MF, *Zodarion alacre* in SD, and *Oecobius machadoi* in GD.

DISCUSSION

Our results show how different ground-living spider assemblages vary according to habitat type in the Cabañeros National Park. Wise (1993) indicates that habitat complexity (e.g., vegetation layers) can be the most important factor determining spider distribution. This relation is often evident in web-building spiders (Enders 1974; Greenstone 1984; Ysnel & Canard 2000); however, it has also been demonstrated for ground-living spiders (Hsieh et al. 2003; Pearce et al. 2004).

Along the first CA axis the different plots have been ordered according to their habitats (Fig. 4). The OP plots (with three vegetation layers and without exploitation) are placed at the negative extreme of this axis. This axis is characterised by a great abundance of *P. festivus* (see Appendix 1). This species, which has a Palearctic distribution, has been found in all habitats. *P. festivus* might have reached OP habitat during an initial stage, when the trees were planted, and found itself benefited by the current status of the National Park. In OP plots, *P. festivus* dominance, low species richness, absence of exclusive spiders (taking into account all samples), low number of endemic species and large number of species shared with other habitats, characterize exotic conifer plantations. Unlike Atauri et al. (2005), who claims that "where forest plantations are an alternative for conserving regional biodiversity, a landscape perspective is needed", we do not think
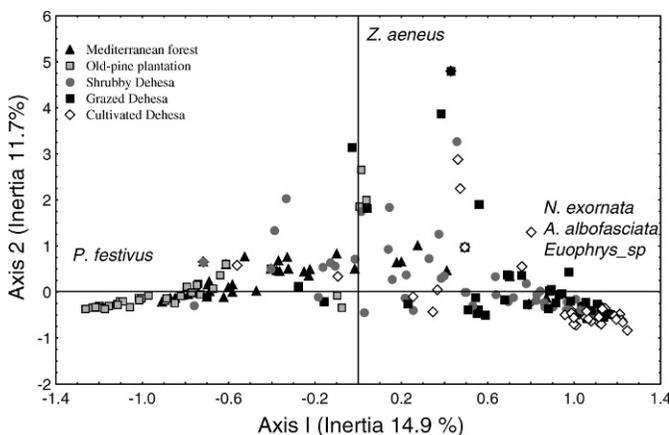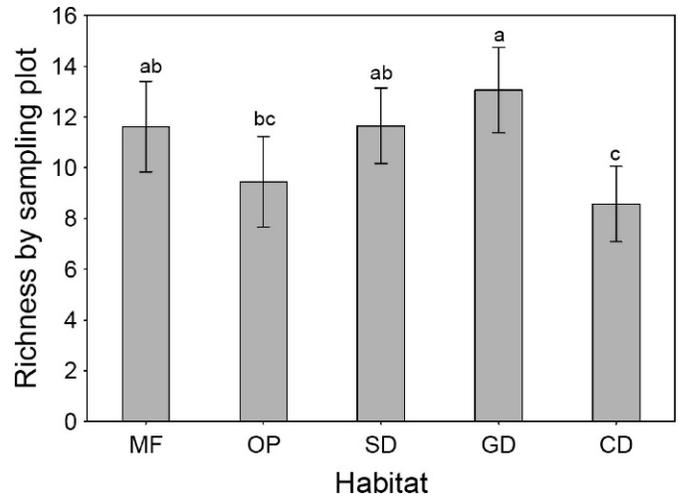

Figure 4.—Sampling plot distribution along the first two axes of the correspondence analysis. Symbols represent each of the five habitats studied. The main contributing species are listed on each end of axis.

Table 3.—IndVal results for the five habitats. Number of localities for Iberian Peninsula, according to Morano (2005) for Spain and Cardoso (2009) for Portugal. Distribution is according to Platnick (2009). Species with most significant presence in each habitat ($P < 0.05$) and their indicator value (I.V.) are presented.

Habitat	Family	Species	I.V.	Spain	Portugal	Distribution
MF	Dysderidae	*Harpactea* sp. n.	55			
MF	Agelenidae	*Tegenaria feminea*	42	51	54 (13)	Iberian endemic. Portugal, Spain
MF	Gnaphosidae	*Micaria coarctata*	42	19	8	Mediterranean to Central Asia
MF	Liocranidae	*Mesiotelus tenuissimus*	41	9	7 (1)	Europe, North Africa, Ukraine, Turkmenistan
MF	Agelenidae	*Tegenaria picta*	33	57	27 (6)	Europe, Russia, North Africa
OP	Dysderidae	*Parachtes loboi*	51	1	0	Spain
OP	Zoropsidae	*Zoropsis media*	44	5	5 (2)	Western Mediterranean
OP	Corinnidae	*Phrurolithus festivus*	35	5	9	Palearctic
OP	Lycosidae	*Trabea cazorla*	35	4	0	Spain, Morocco, Algeria
OP	Agelenidae	*Tegenaria atrica*	31	130	24	Europe
OP	Gnaphosidae	*Zelotes thorelli*	31	17	42 (5)	Southern Europe
OP	Liocranidae	*Scotina celans*	31	13	23 (4)	Europe, Algeria, Russia
SD	Zodariidae	*Zodarion alacre*	37	15	53	Iberian endemic. Portugal, Spain
SD	Salticidae	*Aelurillus aeruginosus*	35	4	0	Mediterranean
SD	Gnaphosidae	*Drassodes rubidus*	22	4	1	Spain to Italy
GD	Gnaphosidae	*Nomisia exornata*	50	29	19 (2)	Europe to Central Asia
GD	Lycosidae	*Alopecosa albofasciata*	35	37	44 (1)	Mediterranean to Central Asia
GD	Gnaphosidae	*Drassodes lapidosus*	29	52	29 (2)	Palearctic
GD	Lycosidae	*Hogna radiata*	28	52	48 (2)	Central Europe to Central Asia, Central Africa
GD	Oecobiidae	*Oecobius machadoi*	24	3	24	Iberian endemic. Portugal, Spain
CD	Gnaphosidae	*Setaphis carmeli*	39	18	10	Mediterranean
CD	Linyphiidae	*Prinerigone vagans*	26	6	18 (1)	Old World

( ) = Number of times that has been collected in the same habitat.

this habitat needs to be protected from an arachnological standpoint. However, these ecosystems hold a certain interest because of the presence of *Parachtes loboi* (Iberian endemic), and as ideal locations for the establishment of species with wide distribution ranges, such as *Zoropsis media*, *Trabaea cazorla*, *Scotina celans* or *Tegenaria atrica*.

Mediterranean forests are highly diverse in growth forms, structure and phenology (Blondel & Aronson 1999). This particular site is located on a stony hillside, with several free boulders and pebbles that offer shelter for spiders, insects, and other animals. The lack of substrate, the thick litter layer and the steep slope that prevents effective soil retention on the rocky surfaces account for the presence of small trees with dense cover. These variables may explain the low diversity of ground-living spiders relative to meadow habitats. Cardoso et al. (2008) found 57 spider species in a similar habitat in Portugal, using the same sampling method, presenting an estimate of richness (Chao1, 67.86) very similar to that found in this study (68). It is worth noting the high number of endemic species, four of which were restricted to this particular habitat (Table 2), likely due to a low degree of human disturbance.

Although the methodology of this study does not allow us to draw strong conclusions on the effect of seasonality, we observed a noticeable seasonal drop in species richness in habitats of *dehesa*, greater than in habitats with higher forest cover, MF and OP. Microclimate conditions below the canopy, such as lower wind exposure and more humidity, and litter regulation of ground temperature are paramount in habitat choice (Wise 1993; Cole et al. 2005) and behavior (Chatzaki et al. 1998; Samu et al. 1999) overall and particularly for ground-living spiders. Hsieh et al. (2003) have reported a strong seasonal influence on spider abundance and

habitat preferences. Seasonality seems to determine not only the duration of growth, development stages, age and size at sexual maturity (Higgins 2000), but also vertical movement and dispersion patterns (Duffey 1969).

SD is the richest habitat (69 species), a value similar to that found by Cardoso et al. (2009) in similar habitats in Portugal (65 species). It is also the habitat with the largest number of endemic species (14). Two species, *Drassodes rubidus* and *Typhochrestus hispaniensis*, were found exclusively in this habitat. A similar richness pattern was found for other animal groups (such as mammals and reptiles) strongly associated with scrub *dehesa* (Martín & López 2003; Díaz et al. 2003a). According to Díaz et al. (2003b), the rich environment that results from the intimate mixing of diverse habitat types (such as forests, scrub, grasslands, and crops) explains their high species richness. This mosaic in the physical environment structure allows the coexistence of species with different habitat preferences, as seen in 29 and 23 species shared with GD and CD, respectively.

GD has a form of disturbance, in this case conditioned by the same grazing activity (regulated, unregulated or normalized) during the last hundred years. The high richness (relative to other habitats in the study) is consistent with the assertion of Perevolotsky & Seligman (1998) that in sub-humid areas with a long grazing history, species diversity increases as a result of expanded grazing intensity and reaches much higher levels of diversity than in regions with a short history. Among the different *dehesa*-type habitats, grazing *dehesa* has the highest passerine bird, earthworm and ground-beetle diversity values (Marañon 1991; Díaz et al. 2003a; Silva et al. 2008).

High values of species richness were found in all *dehesa*-like habitats, including cultivated *dehesa* (CD), despite it having slightly lower values than those of the other two *dehesas*. This

difference probably results from the large number of shared species (23 species with SD and 21 species with GD) and similar colonizing strategy of these species. Sunderland and Samu (2000) investigated the influx of spiders into cultivated fields from surrounding areas. Other studies on ground-living spiders in cultivated areas show that high species richness depends partly on the landscape conformation of surrounding areas. This influence has been addressed at local and regional scales (Samu et al. 1999; Clough et al. 2005; Tscharntke et al. 2005), as well as with different crop types (Schmidt et al. 2005). The high abundance of spider species on cultivated fields must be regarded as potentially useful for the control of harmful insects (Samu et al. 1999; Sunderland & Samu 2000). Spider community structure in agro-ecosystems and grass-lands changes with the latitude (Dennis et al. 2001). The northern-temperate zone of Europe is strongly dominated by small linyphiid spiders that capture tiny insects, including large numbers of aphids, in their sheet webs. A similar situation was reported by Bolduc et al. (2005) in Canada. Samples collected on CD habitats show a strong similarity in ground-living spider community composition to that reported for the northern USA (humid continental climate) where the hunter families, Oxyopidae, Salticidae, Clubionidae, Thomi-sidae, and Lycosidae, predominated (Nyffeler & Sunderland 2003). Additionally, specific Mediterranean families like Gnaphosidae (*Setaphis carmeli* as indicator species) or Titanoecidae were common in the study area. Linyphiid spiders (*Prinerigone vagans* as indicator species) are very common in central and northern Europe, and were also present here (CD with 3 unique species) but at a lower abundance.

Studies by Cardoso et al. (2004) in Portugal suggest the Gnaphosidae and Theridiidae as families with high potential as indicators of habitat that should be conserved in the Iberian Peninsula. These results are consistent with those obtained in this study, because among the indicator species found for each habitat in this study, there is at least one species of gnaphosid.

Mediterranean ecosystems exhibit high ground-living spider richness, especially in protected habitats and in those where human intervention is low. We have shown the existence of a strong relationship between ground-living spider communities and different management conditions. Our work suggests that some ground-living spiders (indicator species) are strongly related to specific habitats and could serve to guide future studies. Since the estimation of ground-living spiders using semi-quantitative sampling is partial, and species that may be adult at another time of the year are not accessible to the methods applied, real total species richness of the investigated area is expected to be somewhat higher (Cardoso et al. 2008).

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Appendix 1:—List of spider species collected by pitfall traps showing relative abundance in the five habits and of each season. MF = Mediterranean Forest, OP = Old-pine Plantation, SD = Scrub Dehesa, GD = Grazed Dehesa, CD = Cultivated Dehesa, s = spring, a = autumn, * = endemic Iberian species.

FAMILY / Species	MF-s	MF-a	OP-s	OP-a	SD-s	SD-a	GD-s	GD-a	CD-s	CD-a
AGELENIDAE										
Tegenaria atrica C.L. Koch 1843	0.33	1.5		6						
Tegenaria feminea Simon 1870*	10.83	13.5	18.33	3	2.5	9	1.33	2	1.5	2
Tegenaria picta Simon 1870	11.83	0.5	12.33		3		4			
CORINNIDAE										
Castianeira badia (Simon 1877)*		1			1			0.5		1
Phrurolinillus lisboensis Wunderlich 1995*	0.33					0.5				
Phrurolithus festivus (C.L. Koch 1835)	33.67	8.5	363	103	12.33	0.5	5		4	
Phrurolithus szilyi Herman 1879					0.5				1	
DYSDERIDAE										
Harpactocrates globifer Ferrández 1986*		3.5								
Parachtes loboi Jiménez, Barriga & Moreno 2006*		0.5	17	1						
Dysdera sp. n.		0.5			0.5		0.5			
Harpactea sp. n.	6.83	0.5			10					
GNAPHOSIDAE										
Drassodes fugax (Simon 1878)		1								
Drassodes lapidosus (Walckenaer 1802)	1.33		2		9.17		26.67		23.17	
Drassodes rubidus (Simon 1878)*					4.5	0.5				
Gnaphosa alacris Simon 1878					2		5.33		5	
Haplodrassus invalidus (O. Pickard-Cambridge 1872)	0.33	3			3	1	6.5	1	12.67	
Leptodrassus albidus Simon 1914					1				0.5	
Leptodrassus femineus (Simon 1873)							1		1.5	
Micaria coarctata (Lucas 1846)	55.67	13	23.17	8	5.83	0.5	30.5	1	1	
Nomisia celerrima Simon 1914	0.5				0.5					
Nomisia exornata (C.L. Koch 1839)					28		80		26	
Setaphis carmeli (O. Pickard-Cambridge 1872)					4.67		15.33		28.83	1
Synophosus sauvage Ovtsharenko, Levy & Platnick 1994					0.5					
Trachyzelotes holosericeus (Simon 1878)	2.17	0.5	1		14		25.67		9.5	
Trachyzelotes sp.					0.5		0.5			
Zelominor algarvensis Snazell & Murphy 1997*					2				2	
Zelotes aeneus (Simon 1878)	1.5	1	0.5	3.5	4.5	9	2.5	34.5	1.83	3
Zelotes dentatidens Simon 1914		0.5					1			
Zelotes fulvopilosus (Simon 1878)	0.67		3		4.5	1	0.5			
Zelotes manius (Simon 1878)						1	1	1	1	1
Zelotes tenuis (L. Koch 1866)					6				12.5	
Zelotes thorelli Simon 1914	23.83	6	50.17	13	26	9.5	8	7	3	4
Zelotes sp. 1.							0.33		1	
Zelotes sp. 2.	1.5									
Zelotes sp. 3.		1								
Zelotes sp. 4.					4.5		3			
HERSILIIDAE										
Hersiliola macullulata (Dufour 1831)			2				4.67	1		
LINYPHIIDAE										
Erigoninae undet. genus									1	
Erigonoplus castellanus (O. Pickard-Cambridge 1875)*							0.5			
Frontinellina frutetorum (C.L. Koch 1834)			1.5	0.5	1				1	
Linyphiidae sp.	0.5									
Meioneta sp. 1.									1.5	
Meioneta sp. 2.							0.5			
Microlinyphia impigra (O. Pickard-Cambridge 1871)		1								
Neriene montana (Clerck 1757)							0.5			
Palludiphantes stygius (Simon 1884)	0.5									
Prinerigone vagans (Audouin 1826)									4	1
Typhochrestus hispaniensis Wunderlich 1995*						1				

Appendix 1—Continued.

FAMILY / Species	MF-s	MF-a	OP-s	OP-a	SD-s	SD-a	GD-s	GD-a	CD-s	CD-a
LIOCRANIDAE										
Agroeca inopina O. Pickard-Cambridge 1886				1						
Agroeca sp.	0.33									
Mesiotelus mauritanicus Simon 1909	8		4.5		6					
Mesiotelus tenuissimus (L. Koch 1866)	7.33	7	5		0.5	1				
Scotina celans (Blackwall 1841)	0.83	1	6	2.5						
LYCOSIDAE										
Alopecosa albofasciata (Brullé 1832)	1.5		10.5		52.5	1	53.67		71.5	
Arctosa perita (Latreille 1799)							0.5			
Arctosa personata (L. Koch 1872)			0.5	2.5	1	2				
Hogna radiata Latreille 1817					12.83		15.33		7.33	1
Pardosa proxima (C.L. Koch 1847)			8.5	3.5	1.5		10		7.33	
Trabaea cazorla Snazell 1983			15	1.5	0.83	1	4	1		
NEMESIIDAE										
Nemesia dubia O. Pickard-Cambridge 1874		3.5	1		2.5	3.5		2		
OECOBIIDAE										
Oecobius machadoi Wunderlich 1995*					0.5	1	15.33			
Uroctea durandi (Latreille 1809)	0.33	1		0.5	0.5	2	1.5	0.5	3	
OONOPIDAE										
Oonops procerus Simon 1882*	0.33				1					
OXYOPIDAE										
Oxyopes heterophthalmus Latreille 1804					0.33					
Oxyopes nigripalpis Kulczynski 1891					0.33					
PALPIMANIDAE										
Palpimanus gibbulus Dufour 1820	0.83	1.5			1	1.5	0.5			
PHILODROMIDAE										
Philodromus dispar Walckenaer 1826	1.5		0.5		1					
Philodromus rufus Walckenaer 1826							0.5			
Thanatus atratus Simon 1875					10.33		13.33		26.83	
Thanatus sp.					1.5		1			
PISAURIDAE										
Pisaura mirabilis (Clerck 1758)					0.5					
SALTICIDAE										
Aelurillus aeruginosus (Simon 1871)					14.67	0.5				
Ballus chalybeius (Walckenaer 1802)							1.5			
Chalcoscirtus infimus (Simon 1868)					1.5				0.5	
Cyrba algerina (Lucas 1846)	0.5				1					
Euophrys sp.	1.33				14.5		27.83	1	40	
Heliophanus sp.					0.5					
Icius hamatus (C.L. Koch 1846)							0.5		1	
Neathea membrosa (Simon 1868)					1				0.5	
Pellenes arciger (Walckenaer 1837)					0.5					
Pellenes geniculatus (Simon 1868)					0.5					
Phlegra sp. 1.	3.5									
Phlegra sp. 2.							1.5	1	2	
Thyene imperialis (Rossi 1846)					0.5					
SCYTODIDAE										
Scytodes velutina Heineken & Lowe 1836	3.33	6.5			14.83	1.5	0.5			
SICARIIDAE										
Loxosceles rufescens (Dufour 1820)					0.5		0.5			
SPARASSIDAE										
Eusparassus dufouri Simon 1932					0.5					
Micrommata ligurina (C.L. Koch 1845)									0.33	

Appendix 1—Continued.

FAMILY / Species	MF-s	MF-a	OP-s	OP-a	SD-s	SD-a	GD-s	GD-a	CD-s	CD-a
THERIDIIDAE										
Achaearanea tepidariorum (C.L. Koch 1841)					0.5		0.33			
Enoplognatha sp.	1.17		0.5						2.5	
Robertus sp.					1				2	
Steatoda paykulliana (Walckenaer 1805)	0.33									
Steatoda phralerata (Panzer 1801)					4.17		15.83		14	
Theridiidae sp.					1.83		1.5		4.5	
THOMISIDAE										
Ozyptila pauxilla (Simon 1870)					6.5		3.83		8	
Xysticus bliteus (Simon 1875)							0.5		1	
Xysticus nubilus Simon 1875					0.5		1		1	
Xysticus robustus (Hahn 1832)								2		
TITANOECIDAE										
Titanoeca hispanica Wunderlich 1995							1		1	
Titanoeca praefica Simon 1870					0.5		1		14.5	
ZODARIIDAE										
Selamia reticulata (Simon 1870)	5.17	2	5	3	10.33	0.5	8.5		2.5	
Zodarion alacre (Simon 1870)*	1.67	2			31	0.5	2.5			
Zodarion segurense Bosman 1994*	1.5									
Zodarion styliferum (Simon 1870)	29.83	3.5	1.5	3.5	16.67	4	37.33	12	6.5	5
ZOROPSIDAE										
Zoropsis media Simon 1878	0.33		4.83	1						