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Cerambycidae (Coleoptera) richness in Mediterranean landscapes of Spain: diversity and community structure analysis

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ABSTRACT The aim of the present work was to analyse the diversity of Cerambycidae (Coleoptera) in 3 Spanish protected Mediterranean natural parks affected by bioclimatic conditions: La Font Roja, Las Lagunas de la Mata-Torrevieja and La Tinença de Benifassà. Sampling was conducted by direct and indirect collection (light and Malaise traps) between 2004 and 2009. During this period, 1,102 specimens, belonging to 61 different species, were captured. Alpha, beta and gamma diversities, as well as the structure of the communities were subsequently analysed. Our results indicate that Tinença de Benifassà has higher diversity than Font Roja and Las Lagunas de la Mata-Torrevieja. Based on analysis of structural models, these communities were observed to be unstable and are composed of only a few abundant species and a large number of rare species. All 3 parks conform to log-series and log-normal distributions. These results demonstrate that it is not possible consider the habitat influence in community structure, since each habitat displays very different botanical and faunal compositions, and climate conditions.

KEY WORDS Cerambycidae; Diversity; Community; Mediterranean landscape.

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INTRODUCTION

Mediterranean ecosystems are very important in biodiversity terms, and are thus considered hotspot areas (Myers et al., 2000). Landscapes and habitats grow in complexity over time, as a consequence of ecological processes. For example, Mediterranean forest landscapes rich in evergreen species frequently intersect with brushwood, pasture, farming and ranching areas.

In close proximity to these areas, however, it is often possible to identify zones which have been reclaimed by highly diverse natural communities after the cessation of human intervention. Despite the huge resistance displayed by Mediterranean biotopes to human pressure, isolation and fragmentation are unavoidable (Pungetti, 2003), resulting in the emergence of isolated patches in the landscape.

Saproxylic beetles play an essential role in these ecosystems, by taking part in decomposition processes essential for the nutrient cycle, and by interacting with other groups of organisms which are also important for the well-being and economy of the ecosystem, such as mites, nematodes, bacteria and fungi (Speight, 1989; Alexander, 2008).

Beetles carry these organisms from tree to tree, aiding their dissemination throughout the habitat and are also involved in pollination (Nieto & Alexander, 2010).

Significant long-term effects to Saproxylic beetles which have been identified include loss of habitat due to logging and wood harvesting and the decline of older, old-growth trees throughout the landscape, as well as the lack of land management strategies aimed at recruiting new tree generations (Buckland & Dinnin, 1993; Nieto & Alexander, 2010).

More short-term and localised threats arise from sanitation works and the removal of old trees due to safety concerns, in places subject to intense human use (Hill et al., 1995; Johns, 1989; Grove & Stork, 1999).

Raising awareness among conservation professionals and resource managers about the needs of saproxylic organisms, who depend on tree aging dynamics and wood decay processes, is crucial, since their role in the ecosystem has far-reaching implications for land management (Kaila et al., 1997; Reid & Kirby, 1996).

A lack of intervention or minimal intervention in formerly wooded pasture areas can deter the renewal of old trees, with very damaging results, whereas livestock grazing may actually be very beneficial for the maintenance of adequate habitats (Nieto & Alexander, 2010).

The death and decay of wood offers a broad range of potential microhabitats for the spatial segregation of different saproxylic insects, according to tree species, tissue type and position within the trees. In addition to this spatial segregation, a temporal segregation follows degradation phases during wood decay. During this process, many stages can be recognised along with their specific saproxylic fauna. Saproxylic insect richness depends on the quantity and quality of dead wood available in the forest, as well as on forest size, fragmentation and management (Mendez Iglesias, 2009).

The Cerambycidae family is one of the richest in saproxylic beetles, with approximately 35,000 catalogued species (Grimaldi & Engel, 2005). Some of these species have frequently been found to be significant for the declaration of internationally important forests (Speight, 1989).

However, despite the large number of studies on this family of beetles, very few studies have been conducted on their diversity and community structure in natural areas, to improve our understanding of this coleoptera community.

In this context, the current work aimed to analyse Cerambycidae community patterns and diversity in three natural parks in the Comunidad Valenciana (Eastern Spain): La Font Roja, Las Lagunas de la Mata-Torrevieja and La Tinença de Benifassà.

These parks enjoy an outstanding position in terms of biodiversity, emphasising their environmental significance due to their particular bioclimatic conditions. To analyse Cerambycidae communities, weekly samples were collected, and abundance, alpha, beta and gamma diversity, as well as community structure were analysed for each park.

MATERIALS AND METHODS

Three natural parks in Comunidad Valenciana were selected for Cerambycidae beetle collection (Figs. 1-3): La Font Roja, Las Lagunas de la Mata-Torrevieja and La Tinença de Benifassà, each of which features peculiar microclimate conditions.

La Font Roja Natural Park is located to the north of Alicante province, and is known for its low level of anthropogenic disturbance. The park extends over 2,298 ha, with a maximum elevation of 1,356 m. The orientation of the hill range favours cool, moist winds from the northeast, resulting in rainfall retention.

This fact, along with the steep slopes and the predominance of limestone, fosters the existence of different landscape units. Among these, deciduous forests, brushwood, scrub rock vegetation, pine forests and agricultural areas can be differentiated. In addition, each face experiences different climate conditions: the north face is classified as upper sub-humid, with annual rainfall between 600-1,000 mm; while the south face is dry, with annual rainfall between 350-600 mm. Due to high average temperatures throughout the year (15-20ºC), and the low average rainfall, the park is classified as dry and thermo-Mediterranean.

Las Lagunas de la Mata-Torrevieja Natural Park is located to the south of Alicante province, and extends over 3,700 ha, 2,100 of which are covered by water. The park is notable for its saline soils, extensive wild orchid population (*Orchis collina* Banks & Sol. ex Russell), differentiated areas of *Senecio auricula* Bourgeau ex Coss and salt marsh plants of the genus *Limonium*, reed and bulrush areas with abundant grass plants such as *Arthrocnemum* sp. and *Juncus* sp., and Mediterranean areas populated by *Quercus coccifera* L., *Pinus halepensis* Mill. and *Thymus* sp. The climate is arid with an annual rainfall below 300 mm and high temperatures.

La Tinença de Benifassà Natural Park is located to the north of Castellon province, and extends over approximately 25,814 ha. The park covers an extensive and well-preserved mountainous area, encompassing numerous and widely varied landscapes associated with medium and high-altitude Mediterranean regimes and hosting a high biodiversity of fauna and flora. It is possible to differentiate forests of *Pinus sylvestris* L., *Pinus uncinata* Mill. and *Fagus sylvatica* L., *Juniperus communis* L., and *Quercus ilex* L., alternating with crops of *Prunus* sp.,

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Figure 1. Natural Park of La Tinença de Benifassà. Figure 2. Natural Park of Font Roja. Figure 3. Natural Park of Las Lagunas de la Mata-Torrevieja. Figure 4. *Arhopalus ferus*. Figure 5. *Stenurella melanura*.

Corylus sp., etc. Climate conditions are continental humid, with annual average temperatures below 12ºC: freezing conditions are possible throughout most of the year. Rainfall varies in different zones according to topographical features and the annual precipitation ranges from 600 to 1,000 l/m^2. The park is contained within the supramediterranean bioclimate.

Samples were collected via direct capture on plants located in the sampling areas and indirect capture with light traps and Malaise traps (Townes model), which complement each other in the capture of specimens.

Specimens were collected between 2004 and 2009 (Figs. 4-11). During this time, each natural park was visited weekly, with a few exceptions due to unforeseeable circumstances. Specimens captured via direct and light trap were kept frozen and specimens captured with Malaise traps were preserved in 70% ethanol until final preparation. Specimens were identified in the lab following criteria established by Vives (2000) and Sama (2002).

Specimens were deposited in the UVEG entomological collection.To analyse diversity and community structure, data were separately organised according to taxa presence in each park, which has been reported to be the most efficient method of interspecific comparisons (Tavares et al., 2001). Using this data, alpha, beta and gamma diversities of each park were calculated.

Alpha diversity was calculated according to taxa richness, abundance and dominance. Taxa richness was used to evaluate richness in each sampling area, and was measured using the Margalef index (Moreno, 2001). Abundance refers to faunal composition in each area (Magurran, 1991), and was measured using the Shannon index, which evaluates equity and indicates the degree of uniformity in species representation (in abundance), taking all data into consideration (Moreno, 2001; Magurran, 1991; Villarreal et al., 2004). Dominance was calculated by measuring genera and species occurrence using the Simpson index, which is often used to measure species dominance values in a given community; negative values represent equity (Magurran, 1991).

The following indexes were used to measure beta diversity: the Jaccard index, which relates the total amount of shared species with the total amount of exclusive species (Moreno, 2001; Villarreal et al., 2004); the complementarity index, which indicates the degree of similarity in species composition and abundance between two or more communities (Moreno, 2001; Villarreal et al., 2004); and cluster analysis, which is used to calculate the degree of correlation based on similarity/dissimilarity. The statistics-processing software PAST was used for calculation of these values. (Hammer et al., 2001).

Finally, gamma diversity, which indicates the degree of diversity of all involved environments, is determined from the richness index of each area (alpha diversity) and the beta diversity (Schluter & Ricklefs, 1993; Villarreal et al., 2004).

In order to complete the diversity analyses and investigate the community structure, log-series, log-normal and broken-stick models were also applied (Magurran, 1991). The log-series model represents an unstable community, composed of a few abundant species and a high number of rare species. The broken-stick model refers to maximum occupation of an environment with equitable sharing of resources between species. Finally, the log-normal reflects an intermediate situation between the previous two models (Soares et al., 2010).

Using the data obtained from the 3 parks, each of these models was applied to calculate the expected number of species – log2, grouping species according to abundance (Magurran, 1991; Tokeshi, 1993; Krebs, 1999). To test the significance of the models, expected species values were compared with those from observed species by chi-square analysis (Zar, 1999).

RESULTS

During the sampling period, a total of 1,102 specimens of Cerambycidae, representing 61 species, were collected (Table 1). Tinença Natural Park (NP) displayed the most abundance and specific richness, with 534 collected specimens and 56 species. Especially abundant were *Agapanthia cardui* (14.55%), *Stenurella melanura* (46.93%) and *Pseudovadonia livida* (10.45%).

La Font Roja NP was second in abundance and specific richness, with 390 specimens and 27 species. The most abundant were *Stenurella melanura* (46.93%) and *Chlorophorus trifasciatus* (16.53%). Finally, Las lagunas de la Mata-Torrevieja NP had 193 specimens and 13 species, of which *Agapanthia cardui*, with 62.69%, was the most abundant. In terms of alpha diversity, Tinença NP showed the most specific richness, with a value of $D_{Mg} = 8.911$,

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Figure 6. *Pseudovadonia livida*. Figure 7. *Stenopterus ater*. Figure 8. *Chlorophorus trifasciatus*. Figure 9. *Monochamus galloprovincialis*. Figure 10. *Agapanthia cardui*. Figure 11. *Agapanthia asphodeli*.

Species	Tinença	%	Font Roja	%	Lagunas	%
Acanthocinus aedilis (Linnaeus 1758)	2	0.37	0	0	0	0
Agapanthia annularis (Olivier 1795)	0	0	0	0	6	3.11
Agapanthia asphodeli (Latreille 1804)	18	3.36	13	3.46	26	2.59
Agapanthia cardui (Linnaeus 1767)	78	14.55	21	5.60	121	62.69
Agapanthia dahli (Richter 1820)	5	0.93	0	0	0	0
Agapanthia villosoviridescens (De Geer 1775)	4	0.75	0	0	0	0
Albana m-griseum Mulsant 1846	0	0	4	1.06	0	0
Anastrangalia sanguinolenta (Linnaeus 1761)	4	0.75	0	0	0	0
Arhopalus ferus (Mulsant 1839)	2	0.37	8	2.13	2	1.04
Arhopalus rusticus (Linnaeus 1758)	3	0.56	6	1.6	0	0
Arhopalus syriacus (Reitter 1895)	2	0.37	0	0	0	0
Aromia moschata (Steven 1809)	1	0.19	0	0	0	0
Calamobius filum (Rossi 1790)	26	4.85	6	1.6	6	3.63
Cerambyx cerdo (Lucas 1842)	3	0.56	3	0.8	0	0
Cerambyx scopolii (Füessly 1775)	4	0.75	0	0	0	0
Certallum ebulinum (Linnaeus 1767)	9	1.68	6	1.6	5	3.11
Chlorophorus pilosus (Forster 1771)	19	3.54	13	3.46	0	0
Chlorophorus ruficornis (Olivier 1790)	2	0.37	0	0	0	0
Chlorophorus sartor (Müller 1766)	1	0.19	2	0.53	0	0
Chlorophorus trifasciatus (Fabricius 1781)	30	5.60	62	16.53	0	0
Chlorophorus varius (Müller 1766)	2	0.37	0	0	0	0
Clytus arietis (Linnaeus 1758)	13	2.43	0	0	0	0
Clytus rhamni Germar 1817	2	0.37	0	0	0	0
Clytus tropicus (Panzer 1795)	1	0.19	0	0	0	0
Ergates faber (Linnaeus 1761)	2	0.37	1	0.26	0	0
Hesperophanes sericeus (Fabricius 1787)	1	0.19	0	0	0	0
Hylotrupes bajulus (Linnaeus 1758)	2	0.37	2	0.53	0	0
Iberodorcadion fuentei (Pic 1899)	1	0.19	0	0	1	0.52
Iberodorcadion suturale (Chevrolat 1862)	0	0	0	0	1	0.52
Monochamus galloprovincialis (Olivier 1795)	6	1.12	2	0.53	2	1.04
Opsilia caerulescens (Scopoli 1763)	23	4.29	16	4.26	13	13.47
Pachitodes cerambiciformis (Schrank 1781)	3	0.56	0	0	0	0
Paracorymbia fulva (De Geer 1775)	2	0.37	0	0	0	0
Paracorymbia otini (Peyerimhoff 1949)	0	0	1	0.26	0	0
Penichroa fasciata (Stephens 1831)	2	0.37	2	0.53	0	0
Phymatodes testaceus (Linnaeus 1758)	0	0	2	0.53	0	0
Phytoecia pustulata (Schrank 1776)	4	0.75	0	0	0	0
Phytoecia virgula (Charpentier 1825)	15	2.80	4	1.06	0	0
Plagionotus arcuatus (Linnaeus 1758)	1	0.19	0	0	0	0
Pogonocherus perroudi Mulsant 1839	1	0.19	0	0	0	0
Prionus coriarius (Linnaeus 1758)	1	0.19	0	0	0	0
Pseudovadonia livida (Fabricius 1777)	56	10.45	0	0	0	0
Purpuricenus budensis (Goeze 1783)	14	2.61	0	0	0	0
Rutpela maculata (Poda 1761)	2	0.37	0	0	0	0
Saperda carcharias (Linnaeus 1758)	2	0.37	0	0	0	0
Stenopterus ater (Linnaeus 1767)	21	3.92	12	3.2	0	0
Stenopterus mauritanicus (Lucas 1846)	6	1.12	0	0	0	0
Stenopterus rufus (Linnaeus 1767)	4	0.75	0	0	0	0
Stenurella bifasciata (Müller 1776)	3	0.56	0	0	0	0
Stenurella melanura (Linnaeus 1758)	63	11.75	176	46.93	0	0
Stenurella nigra (Linnaeus 1758)	36	6.72	0	0	0	0
Stictoleptura cordigera (Füessly 1775)	3	0.56	1	0.26	0	0
Stictoleptura fontenayi (Mulsant 1839)	2	0.37	0	0	0	0
Stictoleptura rubra (Linnaeus 1758)	3	0.56	0	0	0	0
Stictoleptura scutellata (Fabricius 1781)	1	0.19	1	0.26	0	0
Stromatium unicolor (Olivier 1795)	7	1.31	1	0.26	1	0.52
Trichoferus fasciculatus (Faldermann 1837)	3	0.56	1	0.53	7	6.74
Trichoferus griseus (Fabricius 1792)	5	0.93	0	0	0	0
Vesperus xatarti Dufour 1839	4	0.75	9	2.4	2	1.04
Xylotrechus antilope (Schonherr 1817)	2	0.37	0	0	0	0
Xylotrechus arvicola (Olivier 1795)	2	0.37	0	0	0	0
TOTAL	534		375		193	

Table 1. Cerambycidae abundance and average for each Natural Park.

followed by La Font Roja, with 4.218; while Lagunas de Torrevieja showed the least specific richness with a score of 2.28 (Table 2). In addition, according to the Shannon index, proportional abundance was also highest for Tinença (3.212) and lowest for Lagunas (1.399). Furthermore, results obtained with the Simpson index are in agreement with these rankings (0.9346 for Tinença, 0.7417 for Font Roja and 0.5799 for Lagunas) (Table 2).

In order to calculate beta diversity (similarity/dissimilarity), data from the different sampling areas

	Tinença	Font Roja	Lagunas
Species	56	26	13
Specimens	534	375	193
Shannon	3.212	2.032	1.399
Simpson	0.9346	0.7417	0.5799
Margalef	8.911	4.218	2.28

Table 2. Diversity and abundance of Cerambycidae captured.

were compared using the Jaccard index (Table 3). The results show a low level of comparability between species inhabiting each park; the highest value was found for the combination Tinença/Font Roja (0.383), followed by Font Roja/Lagunas (0.344).

The comparability between Tinença and Lagunas was even lower, with a value of only 0.186 (Table 3). This increased similarity between Tinença and Font Roja is due to the fact that the predominant botanical composition is similar in both forests.

On the other hand, the relationship between Font Roja and Lagunas is due to the fact that both natural parks have a high abundance of *Pinus halepensis*, which have an associated fauna of saproxylic insects.Finally, the low comparability value obtained between Tinença and Lagunas is due to significant differences in the botanical composition of these 2 parks.

With respect to the Complementarity Index (C), Tinença/Lagunas showed the highest value (0.813), again indicating the dissimilarity between species captured in each park; while Tinença/Font Roja showed lower complementarity (0.45), indicating a stronger similarity in the specific composition of these parks (Table 3).

These results were subjected to cluster analysis using a Jaccard cluster (Fig. 12). Gamma diversity grouped all 3 parks, yielding a value of 62.

	Tinença	Font Roja	Lagunas	
Tinença	0	0.383	0.186	Jaccard
Font Roja	0.45	0	0.344	
Lagunas	0.813	0.655	0	
	Complementarity			

Table 3. Comparative of Complementarity and Jaccard indexes values for Cerambycidae in each park.

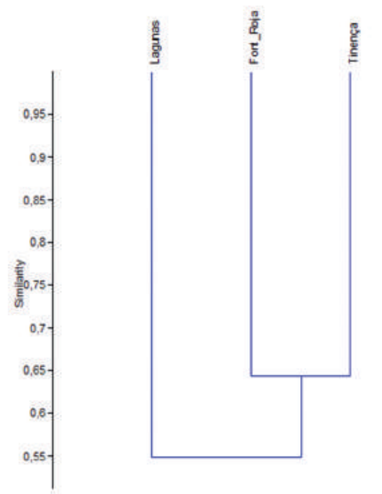

Figure 12. Cluster of Cerambycidae per NP.

Tinença, with 57 captured species, displayed the most diversity, followed by Font Roja (26) and Lagunas (13).

Finally, analysis of the community structure of Cerambycidae in each park revealed agreement with log-series and log-normal models, with p-values greater than 0.05, while no parks matched the broken-stick model (resulting p-values were below 0.05) (Table 4).

	Log-series						*Log-normal*						*Broken-stick*					
	Font Roja		Tinença		Torrevieja		Font Roja		Tinença		Torrevieja		Font Roja		Tinença		Torrevieja	
Class	exp f	obs f	exp f	obs f	exp f	obs f	exp f	obs f	exp f	obs f	exp f	obs f	exp f	obs f	exp f	obs f	exp f	obs f
0	-	-	-	-	-	-	2.75	0	3.75	0	1,16	0	-	-	-	-	-	-
1	9.66	11	23.26	25	4.69	6	7.40	11	17.71	25	3,51	6	3,27	11	10,22	25	1,48	6
2	3.62	3	8.50	13	1.76	0	3.41	3	9.01	13	1,5	0	2,87	3	8,31	13	1,32	0
3	3.76	4	8.49	5	1.83	4	3.54	4	9.17	5	1,53	4	4,74	4	12,25	5	2,22	4
4	3.57	6	7.49	4	1.74	1	2.89	6	6.91	4	1,24	1	6,44	6	13,38	4	3,12	1
5	3.01	1	5.47	6	1.48	1	2.01	1	3.94	6	0,87	1	5,96	1	8,17	6	3,02	1
6	2.09	1	2.87	3	1.04	0	1.11	1	1.72	3	0,49	0	2,56	1	1,67	3	1,32	0
7	1.00	0	0.81	1	0.51	1	0.50	0	0.56	1	0,23	1	0,24	0	0,04	1	0,09	1
8	0.24	1	0.07	0	0.10		0.19	1			0,14	0	0,00	1			0,00	0
9	0.01	0					0.08	0					0,00	0				
	$X^2 = 7.24$		$X^2 = 5.67$		$X^2 = 6.77$		$X^2 = 9.57$		$X^2 = 10.23$		$X^2 = 7.91$		$X^2 = 1271.1$		$X^2 = 57.64$		$X^2 = 28.85$	
	p = 0.5106		p = 0.4607		p = 0.4522		p = 0.2961		p = 0.1152		p = 0.3402		p = 0.0000		p = 0.0000		p = 0.0001	

Table 4. Expected specific frequencies for each of the models used and statistical comparison with observed frequencies.

DISCUSSION

Alpha diversity results show that Tinença de Benifassà NP has higher diversity and specific richness than the other 2 parks. In addition, a comparison of the results for each park reveals notably disparate values, due to wide differences in the number of identified species. This is corroborated by the dissimilar values of the Shannon and Simpson indexes, indicating a lack of similarity in the distribution of dominant species.

Beta diversity results suggest that the three parks under consideration in the present study are markedly different in specific composition. Despite this low similarity, the Complementarity index shows that Tinença NP and Font Roja NP do have some similarities in their specific composition.

Taken together, these data suggest that Tinença NP has the highest biodiversity among the three parks, each of which contains a specific Cerambycidae faunal composition. This correlates with the different botanical compositions and habitats present in each park, since the cycle of each Cerambycidae species (with the exception of a few, less specialised ones) is associated with certain plant species (Linsley, 1959; Vives, 2000). In contrast, analysis of the structural models of these communities indicates that Cerambycidae communities in all of these parks fit log-series and log-normal models, which means that they include a few abundant species and a number of rare species.

Thus, community structure is not determined by habitat, because all three parks display very different faunal and botanical compositions and bioclimates. Community structure also appears to be unaffected by human action, because while Lagunas de la Mata-Torrevieja NP is fully encircled by roads and housing, Tinença NP has remained virtually free from anthropogenic pressure. To conclude, studies on biological diversity and community structure are vital for the development of a better understanding of ecosystems, and for the correct adoption of measures for the conservation and maintenance of biodiversity (Pyle et al., 1981; Pearson & Cassola, 1992; Kremen et al., 1993).

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