



## DIVERSITY OF BEETLE COMMUNITIES IN CORK OAK FOREST OF LARACHE FROM MOROCCO

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### ABSTRACT

**The Cork Oak forest of Larache represents a privileged area and this study explored the spatial distribution of beetles in this area. Three different habitats in 2021 and 2022 were studied by sampling adults using trapping techniques and direct surveys. This study led to collection of 4905 specimens and 229 species belonging to 38 families. Comparisons among the three habitats reveal a significant difference, show varied diets, reflecting the functional groups they fulfill within different habitats. The quantitative and qualitative differences observed have been discussed.**

**Key words:** Diversity, inventory, beetles, functional groups, habitats, forest edge, dense forest, open forest, Cork Oak, Larache, Morocco, sampling, trapping, checklist, species, variations.

The Cork Oak forest of Larache represents a privileged area for acquiring new knowledge in the context of changing land use and land cover. Over the past decades, this region has experienced alarming deterioration of its natural forest stands, resulting from the combination of climatic and anthropogenic factors. This degradation of woody vegetation cover affects and jeopardizes faunal biodiversity and numerous ecosystem services provided in the area (Sánchez-Bayo et al., 2019; Staab et al., 2023). In the context of global changes, insect conservation is of paramount importance. The beetles remain one of the substantial and realistic tools for monitoring and alerting against ecological dysfunction, thus contributing to establishing sustainable management (Lindenmayer et al., 2000; Brustel, 2001; Ghannem et al., 2018). However, our understanding of beetle assemblages, particularly in terms of functional groups and habitat characteristics variation in oak groves forests of the Mediterranean basin, is still scarce and limited. For example, there are only a few studies on saproxylic beetles in Mediterranean forests, such as those conducted in Cabañeros National Park in Central Spain (Micó et al., 2020) and in old woodlands of Mediterranean Cork Oak in Central Italy

(Della et al., 2022). Studies have mainly focused on harmful species (Lumaret et al., 2005). Additionally, the current situation only concerns relatively well-preserved environments of nature reserves (Benhalima, 2004; Mouna, 2013; Benyahia et al., 2015; Bouraada et al., 2016). A recent study highlighted the diversity of beetles in undisturbed and cultivated natural areas (El Harche et al., 2022).

The objective of this study was to understand the diversity of the beetle communities through an inventory for two years of Cork Oak forest habitats (dense forest, open forest and forest edge). Based on identification, the aim was to analyze their trophic relationships to determine the environmental health status. Three hypotheses were tested H1: Plant diversity with adequate understory and deadwood quantity in the dense forest positively would contribute to the functional groups of saprophagous, saproxylophagous and flower visitors. H2: The presence of a forest track and an orchard with various crops near the open forest with human activities such as grazing and soil compaction, which could decrease beetle diversity. H3: The presence of a day in the forest edge, associated

with a high floral diversity, would promote the abundance of ecologically important species, including flowering plants and predators, distinguishing this habitat from the other two.

#### MATERIALS AND METHODS

Three stations representing distinct vegetation and habitats characteristics were inventoried. The first station, “S1” (35°06’42.0”N 6°08’50.1”W), was a dense Cork Oak forest (*Quercus suber* L), characterized by its understory, the presence of varying amounts of deadwood, and a shrub and herbaceous layer. The second station, “S2” (35°02’14.5”N 6°00’25.5”W), was an open Cork Oak forest. Finally, the third station, “S3” (35°12’43.1”N 6°01’57.8”W), was a flowery edge bordering a dense Cork Oak forest. During this study, various trapping systems were used to capture a variety of beetle species: (i) colored pan traps (blue, white, yellow, and orange) installed one meter above the ground, half-filled with a mixture of soapy saltwater. These pan traps were distributed in four traps per station; (ii) Barber traps to intercept surface-active species (Nageleisen & Bouget, 2009), with six plastic cups filled with water and detergent per station; (iii) one interception trap per station was set up to capture xylophagous and saproxylophagous species (Burner et al., 2022). In parallel with these passive techniques, active surveys were conducted along straight transects (1 m x 100 m), in the sampled sites to directly capture encountered individuals.

Trap surveys were conducted every 20 days over a period of 7 months (from April to October) and for two consecutive years (2021-2022). After each collection session, the collected beetles were individually placed in plastic vials, labeled, and then preserved (70% ethyl alcohol). These specimens were later examined in the laboratory, counted and identified at the species and/ or genus level using a binocular microscope and various identification keys. For species confirmation, they were compared to the specimens in the museum’s collections of the CIRF (Center for Innovation, Research and Training) and the Museum of the Scientific Institute of Rabat (Morocco). The identification was validated by the coleopterist Sergi TRÓCOLI. To determine the trophic group for each species, we used a combination of methods including direct observations of feeding behavior and a review of existing scientific literature (Velle, 2004; Carpaneto et al., 2015). To examine the composition and structure of the beetle community, we used various indices of composition (Ramade, 2003;

Frontier, 1983) “species richness (S), relative abundance (AR%)” and structure (Blondel, 1979) “the Shannon-Weaver diversity index (H’), the Simpson index (D) and evenness (E)”. The significance of differences in Shannon, evenness, and Simpson indices at each station was analyzed using a bootstrap test. The Venn Diagram allowed to visualize the number of species specific for each site, of those common to the 3 sites, or different combinations between two sites using PAST version 4.13 (Hammer et al., 2001). A Correspondence factor analysis (CFA) was conducted using XLSTAT 2016 software to determine the distribution of beetle families in their respective habitats. The difference in the species richness, considering both temporal (seasonal) and spatial (habitats) aspects, was analyzed using Two-Way ANOVA (GraphPad Prism 8.0.1).

#### RESULTS AND DISCUSSION

The sampling campaigns in the Cork Oak of Larache led to collection of 4905 specimens belonging to 229 species distributed among 38 families (Table 1). Beetles in the ancient Cork Oak forests in Italy hosted a diversity of 284 species (Della et al., 2022). Investigations gave special attention to the cavities present in the tree trunks allowing the record of many saproxylic species. Otherwise, the high richness of 387 beetle species found in a dense Cork Oak forest in France, could be due to the surrounding of pine stands (Van Meer, 2020). The richness found was higher than that observed in other Cork Oak forests, such as in Algeria (Ganaoui et al., 2020), where 76 species distributed across 61 genera and 21 beetle families were found; only pitfall traps and interception traps were used in the Algerian study. Similarities in families and genera were observed and there existed a marked decrease in beetle richness from the spring season to the winter (Fig. 1). The edge exhibits a richness of 130 species in spring, which drops to 23 in winter, values higher than that observed in the dense forest (S1) and the open forest (S2). The results confirmed significant differences in beetle community richness both in spatial variation ( $p < 0.0001$ ) and temporal variation ( $p = 0.0010$ ). The significant seasonal variation, marked by a decrease from spring to winter, appears to be correlated with the predominant activity of beetles in spring and early summer, when the soil is moistened by rains and the temperature is favourable (El Harche, 2021). The abundance of beetles appears to be closely linked to their lifecycles, characterized by differing reproduction periods among species (Larochelle and Larivière, 2003). As regards the contribution of each site (beta diversity) the species

Table 1. Beetle communities collected from the habitats in the Cork Oak forest of Larache

Families, genus and species	FG	Stations					
		S1		S2		S3	
		ni	AR %	ni	AR %	ni	AR %
<b>Anobiidae (AR%= 0.35; S=1)</b>			0.16				0.68
<i>Stegobium paniceum</i> (Linnaeus, 1758)	X	4	0.16			13	0.68
<b>Anthicidae (AR%= 0.41; S=4)</b>			0.04				1.00
<i>Hirticollis quadriguttatus</i> (Rossi, 1792)	S					9	0.47
<i>Microhoria</i> sp	S	1	0.04				
<i>Omonadus bifasciatus</i> (Rossi, 1792)	S					9	0.47
<i>Omonadus floralis</i> (Linnaeus, 1758)	S					1	0.05
<b>Bruchidae (AR%= 0.33; S=5)</b>			0.31				0.41
<i>Bruchidius biguttatus</i> (Olivier, 1795)	Ph	2	0.08				
<i>Bruchidius bimaculatus</i> (Olivier, 1795)	Ph					1	0.05
<i>Bruchidius foveolatus</i> (Gyllenhal, 1833)	Ph	4	0.16			3	0.16
<i>Bruchidius</i> sp4	Ph	2	0.08			2	0.11
<i>Bruchidius</i> sp5	Ph					2	0.11
<b>Buprestidae (AR%= 1.45; S=9)</b>			0.51		1.1		2.79
<i>Acmaeoderella adspersula</i> (Illiger, 1803)	F	4	0.16			4	0.21
<i>Acmaeoderella discoidea</i> (Fabricius, 1787)	F					1	0.05
<i>Acmaeoderella lanuginosa</i> (Gyllenhal, 1817)	F	1	0.04			21	1.11
<i>Agrilus biguttatus</i> (Fabricius, 1777)	F					1	0.05
<i>Agrilus graminis</i> (Kiesewetter, 1857)	F			3	0.66		
<i>Anthaxia millefolii</i> (Fabricius, 1801)	F	3	0.12	1	0.22	6	0.32
<i>Anthaxia scutellaris</i> (Gené, 1839)	F			1	0.22	7	0.37
<i>Anthaxia umbellatarum</i> (Fabricius, 1787)	F	1	0.04			13	0.68
<i>Habroloma triangulare</i> (Lacordaire, 1835)	F	4	0.16				
<b>Cantharidae (AR%= 0.06; S=1)</b>			0.0				0.16
<i>Rhagonycha</i> sp	F					3	0.16
<b>Carabidae (AR%= 2.98; S=22)</b>			1.57		7.44		3.79
<i>Acupalpus brunnipes</i> (Sturm, 1825)	Pr					2	0.11
<i>Acupalpus</i> sp2	Pr					2	0.11
<i>Agonum emarginatum</i> (Gyllenhal, 1827)	Pr					8	0.42
<i>Bembidion biguttatum</i> (Fabricius, 1779)	Pr					1	0.05
<i>Bembidion bipunctatum</i> (Linnaeus, 1760)	Pr					1	0.05
<i>Bradycellus verbasci</i> (Duftschmid, 1812)	Pr					2	0.11
<i>Carterus rotundicollis</i> (Rambur, 1837)	Pr					1	0.05
<i>Cincidela maroccana</i> (Fabricius, 1801)	Pr	1	0.04				
<i>Cymindis lineola</i> (L. Dufour, 1820)	Pr	1	0.04	1	0.22		
<i>Cymindis platicollis</i> (Say, 1823)	Pr			2	0.44		
<i>Harpalus attenuatus</i> (Stephens, 1828)	Pr					9	0.47
<i>Microlestes abeillei</i> (Brisout de Barneville, 1885)	Pr					4	0.21
<i>Ophonus ardosiacus</i> (Lutshnik, 1922)	Pr	1	0.04			1	0.05
<i>Ophonus subquadratus</i> (Dejean, 1829)	Pr					8	0.42
<i>Paradromius linearis</i> (Olivier, 1795)	Pr					1	0.05
<i>Philorhizus notatus</i> (Stephens, 1827)	Pr	1	0.04				
<i>Pterostichus elongatus</i> (Duftschmid, 1812)	Pr	27	1.06	31	6.78	9	0.47
<i>Scarites terricola terricola</i> (Bonelli, 1813)	Pr	7	0.27				

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<i>Singilis soror soror</i> (Rambur, 1837)	Pr	2	0.08				
<i>Stenolophus abdominalis abdominalis</i> (Gene, 1836)	Pr					14	0.74
<i>Stenolophus teutonius</i> (Schrank, 1781)	Pr					6	0.32
<i>Syntomus foveatus</i> (Geoffroy in Fourcroy, 1785)	Pr					3	0.16
<b>Cerambycidae (AR%= 0.51; S=9)</b>			0.20		0.44		0.95
<i>Agapanthia irrorata</i> (Fabricius, 1787)	F					1	0.05
<i>Alocerus moesiacus</i> (Frivaldszky, 1837)	Sx			2	0.44	1	0.05
<i>Certallum ebulinum</i> (Linné, 1767)	F					2	0.11
<i>Chlorophorus favieri</i> (Farimaire, 1873)	F					1	0.05
<i>Opsilia coeruleascens</i> (Scopoli, 1763)	F					1	0.05
<i>Oxypleurus nodieri</i> (Mulsant, 1839)	Sx					1	0.05
<i>Stenurella approximans</i> (Rosenhauer, 1856)	F	3	0.12			4	0.21
<i>Stictoleptura fontenayi</i> (Mulsant et Rey, 1839)	F	1	0.04				
<i>Trichoferus ilicis</i> (Sama, 1987)	Sx	1	0.04			7	0.37
<b>Chrysomelidae (AR%= 1.37; S=14)</b>			0.24		3.94		2.26
<i>Aphthona euphorbiae</i> (Schrank, 1781)	Ph					1	0.05
<i>Cassida vittata</i> (Villers, 1789)	Ph					23	1.21
<i>Cassida</i> sp2	Ph	1	0.04	1	0.22	2	0.11
<i>Chrysolina bankii</i> (Fabricius, 1775)	Ph	1	0.04				
<i>Chrysolina diluta</i> (Germar, 1823)	Ph			1	0.22		
<i>Cryptocephalus fulvus</i> (Goeze, 1777)	Ph	1	0.04	1	0.22		
<i>Cryptocephalus numidicus</i> (Bourdonné, 1876)	Ph					1	0.05
<i>Lachnaia</i> sp	Ph	1	0.04				
<i>Longitarsus aeneus</i> (Kutschera, 1862)	Ph	1	0.04	2	0.44	7	0.37
<i>Longitarsus ochroleucus</i> (Marsham, 1802)	Ph	1	0.04	13	2.84	2	0.11
<i>Luperus</i> sp	Ph					1	0.05
<i>Oulema melanopus</i> (Linnaeus, 1758)	Ph					1	0.05
<i>Phyllotreta</i> sp	Ph					3	0.16
<i>Psylliodes cuprea</i> (Koch, 1803)	Ph					2	0.11
<b>Cleridae (AR%= 0.02; S=1)</b>							0.05
<i>Tilloidea</i> sp	Sx					1	0.05
<b>Coccinellidae (AR%= 0.77; S=17)</b>			0.39		4.60		0.37
<i>Adalia decempunctata</i> (Linnaeus, 1758)	Pr			1	0.22		
<i>Chilocorus bipustulatus</i> (Linnaeus, 1758)	Pr			1	0.22		
<i>Coccinella septempunctata</i> (Linnaeus, 1758)	Pr			1	0.22		
<i>Exochomus</i> sp	Pr			1	0.22		
<i>Oenopia conglobata</i> (Linnaeus, 1758)	Pr	1	0.04	3	0.66	1	0.05
<i>Oenopia lyncea</i> (Olivier, 1808)	Pr	3	0.12				
<i>Platynaspis luteorubra</i> (Goeze, 1777)	Pr					1	0.05
<i>Rhyzobius litura</i> (Fabricius 1787)	Pr	1	0.04	2	0.44		
<i>Rhyzobius lophantae</i> (Blaisdell, 1892)	Pr			1	0.22	1	0.05
<i>Rodolia cardinalis</i> (Mulsant, 1850)	Pr	1	0.04	1	0.22	1	0.05
<i>Scymnus abietis</i> (Paykull, 1798)	Pr			1	0.22		
<i>Scymnus apetzi</i> (Mulsant, 1846)	Pr			3	0.66	1	0.05
<i>Scymnus impexus</i> (Mulsant, 1850)	Pr			4	0.88		
<i>Scymnus interruptus</i> (Goeze, 1777)	Pr			1	0.22	1	0.05
<i>Scymnus subvillosus</i> (Goeze, 1777)	Pr			1	0.22		
<i>Scymnus suturalis</i> (Westman in Thunberg, 1795)	Pr					1	0.05

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<i>Stethorus punctillum</i> (Weise, 1891)	Pr	4	0.16				
Corylophidae (AR%= 0.06; S=1)							0.16
<i>Arthrolips convexiuscula</i> (Motschulsky, 1849)	M					3	0.16
Cryptophagidae (AR%= 0.02; S=1)							0.05
<i>Cryptophagus</i> sp	M					1	0.05
Curculionidae (AR%= 1.16; S=20)							0.86
						1.09	1.58
<i>Apion frumentarium</i> (Walton, 1844)	Ph	1	0.04			2	0.11
<i>Bagous</i> sp	Ph					1	0.05
<i>Brachyderes incanus</i> (Linné, 1758)	Ph	3	0.12	1	0.22		
<i>Brachyderes pubescens</i> (Boheman, 1833)	Ph	3	0.12	1	0.22	1	0.05
<i>Brachytemnus porcatus</i> (Germar, 1823)	X	3	0.12			1	0.05
<i>Ceutorhynchus pallidactylus</i> (Marsham, 1802)	Ph	1	0.04				
<i>Coeliodes ruber</i> (T. Marsham, 1802)	Ph					2	0.11
<i>Curculio pyrrhoceras</i> (T. Marsham, 1802)	Ph	4	0.16				
<i>Hemitrichapion reflexum</i> (Gyllenhal, 1833)	Ph	3	0.12			3	0.16
<i>Lixus juncii</i> (Boheman, 1835)	Ph	1	0.04			4	0.21
<i>Microplontus rugulosus</i> (J.F.W. Herbst, 1795)	Ph					1	0.05
<i>Orchestes irroratus</i> (Kiesenwetter, 1852)	Ph	2	0.08				
<i>Sitona callosus</i> (Gyllenhal, 1834)	Ph			1	0.22		
<i>Sitona lineatus</i> (Linnaeus, 1758)	Ph					5	0.26
<i>Sitona lineellus</i> (Bonsdorff, 1785)	Ph					2	0.11
<i>Sitona longulus</i> (Gyllenhal, 1834)	Ph			1	0.22	1	0.05
<i>Sitona</i> sp	Ph	1	0.04			1	0.05
<i>Tychius cuprifer</i> (Panzer, 1799)	Ph			1	0.22		
<i>Tychius pusillus</i> (Germar, 1842)	Ph					6	0.32
Dermestidae (AR%= 2.00; S=9)							0.57
						1.09	3.89
<i>Anthrenus flavipes</i> (LeConte, 1854)	F					4	0.21
<i>Anthrenus fuscus</i> (Olivier, 1790)	F	1	0.04	1	0.22	6	0.32
<i>Anthrenus museorum</i> (Linnaeus, 1761)	F					1	0.05
<i>Anthrenus pimpinellae</i> (Fabricius, 1775)	F					1	0.05
<i>Anthrenus</i> sp	F	3	0.12			11	0.58
<i>Attagenus bifasciatus</i> (Fabricius, 1787)	F	7	0.27	1	0.22	43	2.26
<i>Dermestes frischii</i> (Kugelann, 1792)	N	4	0.16	3	0.66	6	0.32
<i>Orphilus niger</i> (Rossi, 1790)	N					1	0.05
<i>Trogoderma granarium</i> (Everts, 1898)	F	4	0.16			1	0.05
Dryopidae (AR%= 0.02; S=1)							0.05
<i>Dryops luridus</i> (Erichson, 1847)	Ph					1	0.05
Elateridae (AR%= 0.45; S=5)							0.12
						1.09	0.74
<i>Athous</i> sp	Sx	1	0.04			3	0.16
<i>Cardiophorus rufipes</i> (Buysson, 1902)	Sx	2	0.08	5	1.09	6	0.32
<i>Cardiophorus</i> sp2	Sx					1	0.05
<i>Conoderus bellus</i> (Say, 1824)	Sx					1	0.05
<i>Drasterius bimaculatus</i> (Rossi, 1790)	Sx					3	0.16
Erotylidae (AR%= 0.02; S=1)							0.05
<i>Triplax lacordairei</i> (Crotch, 1870)	M					1	0.05
Geotrupidae (AR%= 4.40; S=2)							5.14
						14.44	1.00
<i>Thorectes distinctus</i> (Marseul, 1878)	C	131	5.14	65	14.22	19	1.00
<i>Typhaeus typhoeus</i> (Linnaeus, 1758)	C			1	0.22		

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(Table 1 contd.)

Glaphyridae (AR%= 0.43; S=2)				0.05			1.05
<i>Anthyypna meles</i> (Fabricius, 1792)	F	1	0.04			1	0.05
<i>Eulasia goudoti</i> (Laporte, 1840)	F					19	1
Histeridae (AR%= 0.27; S=2)				0.31			0.26
<i>Hypocaccus rugiceps</i> (Duftschmid, 1805)	N					4	0.21
<i>Saprinus proximus simimmimis</i> (Wollaston, 1865)	N	8	0.31			1	0.05
Hydraenidae (AR%= 0.02; S=1)						0.22	
<i>Ochthebius bicolon</i> (Germar, 1823)	M			1	0.22		
Hydrophilidae (AR%= 0.08; S=3)							0.21
<i>Cercyon obsoletus</i> (Gyllenhal, 1808)	Pr					1	0.05
<i>Cercyon</i> sp2	Pr					1	0.05
<i>Sphaeridium scarabaeoides</i> (Linnaeus, 1758)	Pr					2	0.11
Laemophloeidae (AR%= 0.06; S=3)						0.22	0.11
<i>Laemophloeus monilis</i> (Fabricius, 1787)	M			1	0.22		
<i>Laemophloeus muticus</i> (Fabricius, 1781)	M					1	0.05
<i>Leptophloeus</i> sp	M					1	0.05
Latridiidae (AR%= 0.08; S=3)				0.04			0.16
<i>Corticarina curta</i> (Wollaston, 1854)	M					1	0.05
<i>Enicmus transversus</i> (Olivier, 1790)	M	1	0.04				
<i>Stephostethus productus</i> (Rosenhauer, 1856)	M					2	0.11
Meloidae (AR%= 0.45; S=4)				0.82			0.05
<i>Berberomeloe majalis</i> (Linnaeus, 1758)	F	1	0.04				
<i>Croscherichia paykulli</i> (Billberg, 1813)	F	1	0.04				
<i>Hycleus rufipalpis</i> (Escalera, 1909)	F	19	0.75				
<i>Mylabris variabilis</i> (Pallas, 1781)	F					1	0.05
Melyridae (AR%= 11.44; S=9)				7.42	5.03		18.37
<i>Aplocnemus</i> sp1	F					1	0.05
<i>Aplocnemus virens</i> (Suffrian, 1843)	F	1	0.04			6	0.32
<i>Clanoptilus</i> sp	F	1	0.04				
<i>Colotes javeti</i> (Jacquelin du Val, 1852)	F	1	0.04				
<i>Danacea</i> sp	F					1	0.05
<i>Dasytes nigroaeneus</i> (Küster, 1850)	F	89	3.49	14	3.06	237	12.47
<i>Dasytes terminalis</i> (Jacquelin du Val, 1863)	F	90	3.53	5	1.09	102	5.37
<i>Psilothrix viridicoerulea</i> (Geoffroy, 1758)	F	1	0.04			2	0.11
<i>Troglops furcatus</i> (Perrin, 1885)	F	6	0.24	4	0.88		
Mordellidae (AR%= 4.42; S=4)				0.16		0.22	11.16
<i>Mediimorda bipunctata</i> (Germar, 1827)	F			1	0.22	44	2.32
<i>Mordella aculeata</i> (Linnaeus, 1758)	F	3	0.12			5	0.26
<i>Mordellistena</i> sp	F					1	0.05
<i>Variimorda villosa</i> (Schrank von Paula, 1781)	F	1	0.04			162	8.53
Nitidulidae (AR%= 1.02; S=7)				0.67		0.88	1.53
<i>Acanthogethes</i> sp (Olivier, 1790)	Ph	2	0.08			8	0.42
<i>Carpophilus hemipterus</i> (Linnaeus, 1758)	Ph			1	0.22	1	0.05
<i>Epuraea latipes</i> (Grouvelle, 1896)	Ph					2	0.11
<i>Meligethes aeneus</i> (Fabricius, 1775)	Ph	9	0.35	2	0.44	10	0.53
<i>Meligethes viridescens</i> (Fabricius, 1787)	Ph	3	0.12	1	0.22	4	0.21
<i>Nitidula</i> sp	Ph	3	0.12			4	0.21

(contd.)

(Table 1 contd.)

Oedemeridae (AR%= 5.24; S=3)			6.20		0.22		5.16
<i>Chrysanthia viridissima</i> (Linnaeus, 1758)	F	132	5.18				
<i>Oedemera barbara</i> (Fabricius, 1792)	F	26	1.02	1	0.22	55	2.89
<i>Oedemera marmorata</i> (Erichson, 1841)	F					43	2.26
Phalacridae (AR%= 0.35; S=2)			0.08		0.22		0.74
<i>Olibrus pygmaeus</i> (Sturm, 1807)	M	2	0.08	1	0.22	10	0.53
<i>Phalacrus coruscus</i> (Panzer, 1797)	M					4	0.21
Ptinidae (AR%= 0.10; S=3)			0.04		0.22		0.16
<i>Dignomus irroratus</i> (Kiesenwetter, 1851)	X	1	0.04			2	0.11
<i>Dignomus</i> sp2	X					1	0.05
<i>Ptinus</i> sp	X			1	0.22		
Scarabaeidae (AR%= 5.93; S=25)			6.51		2.41		6.00
<i>Amphimallon</i> sp	Ph					2	0.11
<i>Anisoplia baetica</i> (Erichson, 1847)	F					4	0.21
<i>Anthoplia floricola</i> (Fabricius 1787)	F					1	0.05
<i>Aphodius diecki</i> (Harold, 1870)	C					1	0.05
<i>Aphodius</i> sp2	C					1	0.05
<i>Blitopertha lineata</i> (Fabricius, 1798)	F					1	0.05
<i>Euserica mamorensis</i> (Baraud, 1965)	Ph	8	0.31	3	0.66	7	0.37
<i>Gymnopleurus flagellatus</i> (Fabricius, 1787)	C	1	0.04				
<i>Gymnopleurus sturmii</i> (MacLeay, 1821)	C	1	0.04				
<i>Hoplia africana</i> (Escalera, 1914)	F					20	1.05
<i>Hoplia bilineata</i> (Fabricius, 1801)	F					5	0.26
<i>Hoplia philanthus</i> (Fuessly, 1775)	F	1	0.04			14	0.74
<i>Hymenoplia</i> sp (Reitter, 1890)	F			1	0.22	1	0.05
<i>Onthophagus maki</i> (Illiger, 1803)	C	10	0.39				
<i>Onthophagus</i> sp2	C	9	0.35			3	0.16
<i>Oxythyrea funesta</i> (Poda, 1761)	F	3	0.12			30	1.58
<i>Paratriodonta</i> sp	F	14	0.55			4	0.21
<i>Pleurophorus caesus</i> (Creutzer, 1796)	C					7	0.37
<i>Protaetia opaca</i> (Fabricius, 1787)	F	1	0.04			8	0.42
<i>Rhizotrogus</i> sp	Ph					1	0.05
<i>Scarabaeus cicatricosus</i> (P.H. Lucas, 1846)	C	102	4.00	6	1.31	1	0.05
<i>Scarabaeus sacer</i> (Linnaeus, 1758)	C	11	0.43				
<i>Sphodroxia maroccana</i> (Ley, 1923)	Ph	4	0.16	1	0.22		
<i>Trichius zonatus</i> (Germar, 1831)	F					2	0.11
<i>Tropinota squalida</i> (Brullé, 1832)	F	1	0.04			1	0.05
Scolytidae (AR (%) = 0.33; S=5)			0.08		0.06		0.58
<i>Hypoborus ficus</i> (Erichson, 1836)	X					2	0.11
<i>Platypus cylindrus</i> (Fabricius, 1792)	X	1	0.04	3	0.66		
<i>Scolytus</i> sp1	X					1	0.05
<i>Scolytus</i> sp2	X					1	0.05
<i>Xyleborus monographus</i> (Fabricius, 1792)	X	1	0.04			7	0.37
Scraptiidae (AR%= 0.39; S=2)			0.16				0.79
<i>Anaspis</i> sp	F	4	0.16			8	0.42
<i>Scraptia fuscula</i> (Müller, 1821)	F					7	0.37
Staphylinidae (AR%= 1.90; S=7)			0.12		0.22		4.68
<i>Oxytelus sculptus</i> (Gravenhorst, 1806)	Pr/N	2	0.08			2	0.11

(contd.)

(contd. Table 1)

<i>Philonthus longicornis</i> (Stephens, 1832)	Pr/N				20	1.05
<i>Spedophilus marshami</i> (Stephens, 1832)	Pr/N				1	0.05
<i>Stenus</i> sp	Pr/N				6	0.32
<i>Tachyporus hyponorum</i> (Fabricius, 1775)	Pr/N		1	0.22	2	0.11
<i>Tachyporus nitidulus</i> (Fabricius, 1781)	Pr/N				11	0.58
<i>Xantholinus linearis</i> (Olivier, 1795)	Pr/N	1	0.04		47	2.47
<b>Tenebrionidae (AR%= 51.03; S=21)</b>			<b>67.03</b>		<b>53.83</b>	<b>28.89</b>
<i>Adelostoma sulcatum</i> (Duponchel, 1829)	S	1	0.04	1	0.22	
<i>Alphasida</i> sp	S				2	0.11
<i>Boromorpha tagenoides</i> (Lucas, 1846)	S				1	0.05
<i>Cnemeplatia atropos</i> (Costa, 1847)	S				2	0.11
<i>Cossyphus hoffmanseggi</i> (Herbst, 1797)	S				9	0.47
<i>Erodium</i> sp1	S	400	15.70	30	6.56	23
<i>Erodium</i> sp2	S	45	1.77	6	1.31	
<i>Gonocephalum granulatum granulatum</i> (Fabricius, 1792)	S				1	0.05
<i>Heliotaurus ruficollis</i> (Fabricius, 1781)	F	10	0.39		475	25.00
<i>Isomira melanophthalma</i> (Lucas, 1846)	F	1	0.04		1	0.05
<i>Latheticus oryzae</i> (Waterhouse, 1880)	S				1	0.05
<i>Opatrum</i> sp	S				2	0.11
<i>Pachychila</i> sp1	S	503	19.74	8	1.75	20
<i>Pachychila</i> sp2	S	337	13.23	55	12.04	
<i>Pimelia chrysoloides subris</i> (Koch, 1941)	S	100	3.92	13	2.84	3
<i>Pimelia</i> sp2	S	184	7.22	125	27.35	
<i>Sepidium bidentatum</i> (Solier, 1843)	S	41	1.61		5	0.26
<i>Stenosis</i> sp	S	16	0.63	2	0.44	4
<i>Tenebrio</i> sp1	S	1	0.04			
<i>Zophosis minuta</i> (Fabricius, 1775)	S	69	2.71	6	1.31	
<b>Trogossitidae (AR%= 0.04; S=1)</b>			<b>0.04</b>			<b>0.05</b>
<i>Temnoscheila caerulea</i> (Olivier, 1790)	Pr	1	0.04		1	0.05
<b>Zopheridae (AR%= 0.06; S=2)</b>					<b>0.44</b>	<b>0.05</b>
<i>Colobicus</i> sp	S			1	0.22	
<i>Endophloeus markovichianus</i> (Piller & Mitterpacher, 1783)	M			1	0.22	1
<b>Total No. of specimens</b>		<b>2548</b>		<b>457</b>		<b>1900</b>
<b>Taxonomic richness</b>		<b>104</b>		<b>65</b>		<b>173</b>

FG= Feeding Groups (adults): X= Xylophagous; S= Saprophagous; Ph= Phytophagous; F= Flower visitors; Pr= Prédators; Sx= Sapro-xylophagous; M= Mycophagous; C= Coprophagous; N= Nérophagous. ni= Number of individuals of a given species; N=Total number of individuals; S= Taxonomic richness; S1= Dense forest; S2= Open forest; S3= Forest edge.

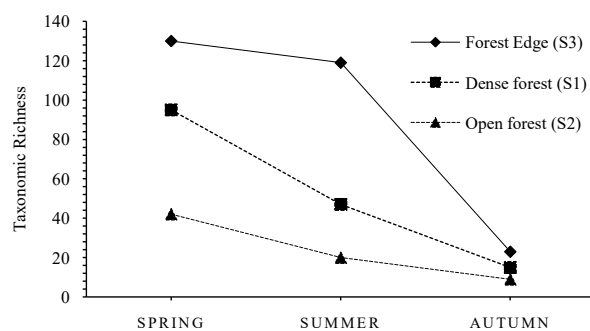


Fig. 1. Seasonal dynamics of beetle communities

diversity as shown in the Venn diagram (Fig. 2), it is striking that only 25 species, i.e. around 11%, were common to the three sites. Only 63 species, making around 27.5%, were shared by two of the three sites. The originality of each type of forest was highlighted by 141 species unique to a given site, corresponding to around 61.5%. The varied distribution of feeding groups within these 25 core species demonstrates the complexity and ecological richness of the sites studied. This mixture of food groups reflects significant functional diversity among the species common to the three sites. The

Table 2. Two-way ANOVA- the variation of beetle richness over seasons and habitats

Annova two-way	% of tot var	SS	DF	MS	P value	S
Temporality	36.20	12630	6	2105	P=0.0010	**
Spatiality	55.10	19226	2	9613	P<0.0001	***

% of tot var: % of total variation, SS: Sum of squares, DF: Degrees of freedom, MS: Mean square, S: Significance. \*\*: p< 0.05, \*\*\*: p< 0.001.

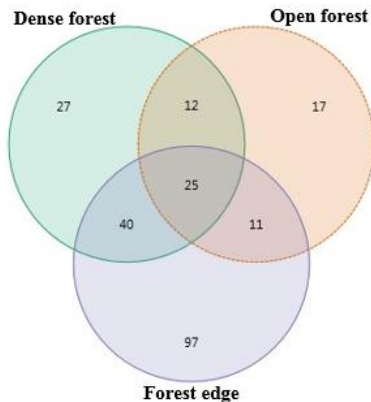


Fig. 2. Unique and shared beetles species between dense forest (S1), open forest (S2) and forest edge (S3)

presence of species endemic to Morocco (Bezdek, 2006; Lobl et al., 2008), notably *Euserica mamorensis* (Baraud, 1965) and *Pimelia chrysomeloides subris* (Koch, 1941), also highlights the importance of these habitats for the conservation of local biodiversity. In addition, the inclusion of a corophagous species on the Mediterranean red list (Numa et al., 2020), *Scarabaeus cicatricosus* (P.H. Lucas, 1846), highlights the need to preserve this ecosystem to protect vulnerable species. In contrast, the species restricted in one site represent > 60%.

The clear distinction observed between habitats, with greater beetle richness at the forest edge in spring and summer compared to other habitats, supports the hypothesis regarding the differential impact of habitats on diversity. The analysis of these ecological indices highlights that biological diversity varies significantly among the stations (Fig. 3). Notably, Station 3 (S3) exhibited the highest Shannon index value of 3.45, coinciding with the highest species richness of 173 species, including 93 specific ones. Thus, the hypothesis that both plant diversity and the presence of water resources (Daya) significantly contribute to faunal richness i.e., was significantly different from S1 (2.86; p=0.001) but not from S2 (2.81; p=0.7). This suggests that S3 has a higher species diversity and a more balanced distribution of species compared to S1 and S2. In contrast, while the dense forest (S1)

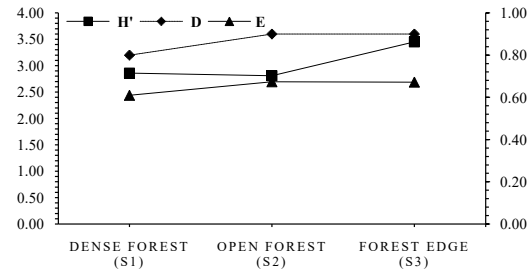


Fig. 3. Variation of Shannon-Wiener (H'), Simpson (D), and evenness (E) indices in the three studied habitats

displayed relatively high species richness (104 species, including 27 specific ones), its Shannon index values were lower than those of S3, indicating lower overall diversity and a less balanced species distribution. Additionally, the presence of an orchard adjacent to the forest track, cultivated with various crops, suggests potential insecticide use, which could adversely affect the local ecosystem and disrupt the assemblages of certain beetles (Serrano et al., 2005; Foley et al., 2005). In terms of evenness (E), S1 (0.61) and S2 (0.67) did not show significant differences (p=0.9), nor did S2 and S3 (p=1). However, a notable difference in species distribution was observed between S1 and S3 (p=0.001), indicating a more even distribution of species at S3. For the Simpson index, S2 (0.8) significantly differed from S1 (0.9; p=0.002), with S3 also indicating a slight increase in the dominance of one or a few species (0.9; p=0.001). Nevertheless, S1 and S3 did not show significant differences (p=0.02).

Evenness suggested a similar distribution of species abundances between S1 and S2, as well as between S3 and S2. The open forest (S2) had a lower number of species (65) and fewer specific species (17), with diversity index values close to those of S1 and only slight differences in species distribution. This reinforces the hypothesis that the proximity of S2 to a forest track may lead to disturbances within the beetle communities. The correspondence factor analysis (CFA) helped in assigning the families of beetles to their specific habitats (Fig. 4). This shows that beetles have varied diets, considering the range of functions they fulfill within different habitats (Grandjean,

2018). The identified species were categorized into different feeding groups based on the functions they perform and their interactions with other organisms within the various habitats (Fig. 5). The predominance of saprophagous species in S1 (dense forest) and S2 (open forest), accounting for 66% and 54.5% of the recorded individuals, respectively, seemed to be

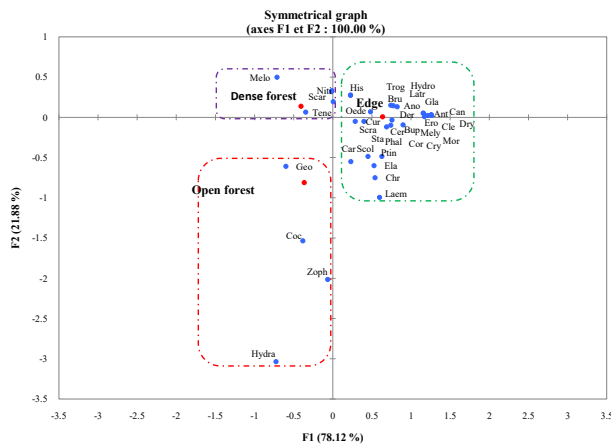


Fig. 4. Projection of the stations and the families of beetle communities (on the factorial plane F1\*F2 of the CFA)

CFA of 38 families of the beetle communities distributed in the three studied habitats in the Suberaie de Larache. Abbreviations: Ano-Anobidae, Ant-Anthicidae, Bru-Bruchidae, Bup-Buprestida, Can-Cantharidae, Car-Carabidae, Cer-Cerambycidae, Chr-Chrysomelidae, Cle-Cleridae, Coc-Coccinellidae, Cor-Corylophidae, Cry-Cryptophagidae, Cur-Curculionidae, Der-Dermestidae, Dry-Dryopidae, Ela-Elateridae, Ero-Erotylidae, Geo-Geotrupidae, Gla-Glyphyridae, His-Histeridae, Hydra-Hydraenidae, Hydro-Hydrophilidae, Laem-Laemophloeidae, Latr-Latridiidae, Melo-Meloidae, Mely-Melyridae, Mor-Mordellidae, Niti-Nitidulidae, Oede-Oedemeridae, Phal-Phalacridae, Ptin-Ptinidae, Scar-Scarabaeidae, Scol-Scolytidae, Scra-Scraptiidae, Sta-Staphylinidae, Tene-Tenebrionidae, Trog-Trogossitidae, Zoph-Zopheridae.

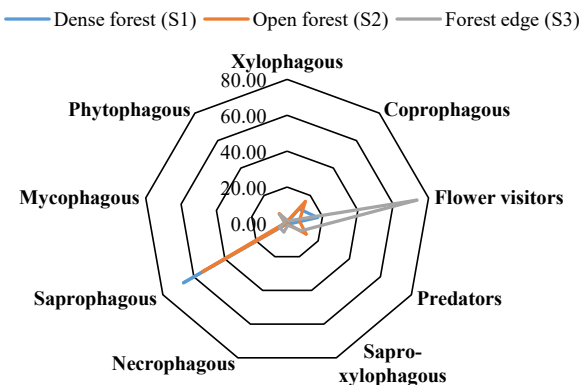


Fig. 5. Radar chart: Abundance profiles of the different feeding groups in the three studied habitats, in percentages: Dense forest (S1), open forest (S2) and Fforest edge (S3)

associated with their essential role in the decomposition process of organic matter in the soil. This trend can be explained by the strong representation of species from the Tenebrionidae family compared to other families. Their dominance is attributed to their resistance to harsh environments and their ability to exploit a wide range of food resources, as well as their adaptations to hot and dry microclimates (Fattorini, 2024). Species from this group, notably the genera *Erodius* (19.74%), *Pachychila* (15.70%), which were abundant in S1, and *Pimelia* (27.35%), well represented in S2, play a crucial role in nutrient recycling and the decomposition of dead organic matter (Labrique and Gomy, 2010; Coulis, 2015). Alongside saprophagous, the coprophagous group was well represented in S2 (Open forest) and S1 (Dense forest), accounting for 15.75% and 10.40% of the total population, respectively, due to important grazing activity. The presence of livestock in the forest environment promoted the maintenance of a particular fauna associated with dung (Daas et al., 2016), often linked to specific ecological niches (Lumaret, 1983). Their contribution to the decomposition of organic matter can also influence ecosystem dynamics by enhancing soil fertility (Chao et al., 2013; Perrin et al., 2019).

Coprophagous ones were represented by the Scarabaeidae family (6.51%), strongly associated with S1 represented by *Scarabaeus cicatricosus* (Lucas) (4%), and the Geotrupidae family (14.44%), associated with S2 represented by *Thorectes distinctus* (Marseul) (14.22%). On the other hand, the predominance of flower visitor species in S3 (73.37%) might indicate their dependence on floral resources present in this habitat. Indeed, the abundance of several flower visitors species at the edge, such as *Heliotaurus ruficollis* (F) (25%), *Dasytes nigroaeneus* (Küster) (12.47%), and *Variimorda villosa* (Schrank von Paula) (8.53%), suggests a strong interconnection between these beetles and the specific floral diversity in this area. These species are adapted to exploit flowers as a food source (nectar and pollen). The flower visitors are also quite abundant in S1, representing 17.27%, reinforcing this connection between flower visitors beetles and certain flowering plants: *Helianthemum lavandulifolium* (Mill) and *Halimium halimifolium* (Cronquist). Otherwise, the limited presence of other feeding groups, which do not exceed 7% in the three studied habitats, could be partly explained by the abundance of predators, especially in the open forest (S2) and the forest edge (S3), representing 12.25% and 8.89%, respectively. The predator species were represented by the families

Staphylinidae and Carabidae. Predators can exert selective pressure on other feeding groups, thus limiting their abundance.

However, although one might have expected a high abundance of saproxylophagous beetles, especially in S1 (Dense forest), study did not validate this hypothesis. The rarity of these beetles, which are typically associated with the decomposition of dead wood, raises an interesting question. Indeed, the survival and life cycle of species in this group depend closely on the availability of cavities and crevices in old trees, which provide essential refuge and breeding sites for saproxylic species. It is important to note that this study did not include pitfall traps placed in tree cavities, as done by Della Rocca et al. (2022). Consequently, this study may have missed capturing some saproxylic beetle species that rely on such specific microhabitats. Additionally, the collection of dead wood for domestic heating may have a role, but this hypothesis warrants further investigations (Della Rocca et al., 2014). Further experiments include the use of adapted traps and the collection or even addition of deadwood, to interpret the “poor” diversity of this feeding group. Moreover, study cannot exclude the potential influence of stable microclimatic conditions and advanced stages of wood as emphasized by Della Rocca et al. (2022) on the diversity of saproxylic beetles of Cork Oak forest. It was also noted that the group of xylophagous beetles was also poorly represented in the three habitats. This observation may partly explain the good health status of the Cork Oak of Larache. Since, xylophagous beetles are recognized as potential causal agents of the weakening of Cork Oaks, thus influencing their regeneration (Villemant and Fraval, 1993).

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#### AUTHOR CONTRIBUTION STATEMENT

Conceptualization: A S, D P, N M. Data curation: A S, N M, H H. Formal analysis: A S, D P. Funding acquisition: A S, N M. Investigation: A S, N M. Methodology: A S, N M, D P, S T. Resources: A S, N M. Supervision: N M, D P. Project administration: L R, N M. Validation: D P, N M, L R. Visualization: D P. Writing – original draft: A S, D P. Writing – review and editing: A S, D P, N M, S T.

#### CONFLICT OF INTEREST

No conflict of interest.

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