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Response of beetle communities and functional groups to changes in structural and compositional biodiversity of cork oak forest and agricultural landscapes in the northwest of Morocco

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Abstract

Response of beetle communities and functional groups to changes in structural and compositional biodiversity of cork oak forest and agricultural landscapes in the northwest of Morocco. The geographical location of Morocco provides an exceptionally biodiverse environment. This study aims to fill knowledge gaps regarding the biodiversity of beetles in the northwest of Morocco. We explored cork oak forests *Quercus suber* L. in Larache and the Gharb plain over two consecutive years (2021 and 2022) and performed an inventory of beetles. We captured and identified 5,405 specimens belonging to 246 species and 39 families. Three trends were evident in this study: 1) the most diverse family was Tenebrionidae, a family with a distinct affinity to Mediterranean climates; 2) we found few sapro–xylophagous, xylophagous, and coprophagous beetles in the study; and 3) our findings indicate that the Larache cork oak forest plays a vital ecological role in the area as beetle biodiversity and functional groups were much higher in the forested sectors than in nearby agricultural areas.

Dataset published through GBIF (DOI: 10.15470/kklmel).

Key words: Beetles, Larache cork oak forest, Agricultural sector, Morocco

Resumen

Respuesta de las comunidades de escarabajos y de los grupos funcionales a los cambios en la biodiversidad estructural y compositiva de los bosques de alcornoques y de los paisajes agrícolas del noroeste de Marruecos. La ubicación geográfica de Marruecos proporciona una biodiversidad excepcional. Este estudio tiene como objetivo llenar los vacíos sobre la biodiversidad de los escarabajos en el noroeste de Marruecos, a partir de la exploración de los bosques de alcornoques *Quercus suber* L. de Larache y la llanura de Gharb, durante dos años consecutivos (2021 y 2022), a través de un inventario de escarabajos. Los resultados obtenidos permitieron la identificación de 5.405 especímenes pertenecientes a

246 especies y 39 familias. Tres tendencias fueron evidentes en este estudio: 1) La familia Tenebrionidae, con una afinidad distintiva por los climas mediterráneos, fue la más diversa en cuanto a especies; 2) se encontraron pocos escarabajos saproxilófagos, xilófagos y coprófagos; y 3) el bosque de alcornoques de Larache desempeña un papel ecológico vital en la zona, ya que la biodiversidad de escarabajos y sus grupos funcionales es mucho más alta en los sectores forestales que en las áreas agrícolas cercanas.

Datos publicados en GBIF (DOI: 10.15470/kklmel).

Palabras clave: Escarabajos, Bosque de alcornoques de Larache, Sector agrícola, Noroeste, Marruecos

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Resum

Resposta de les comunitats d'escarabats i dels grups funcionals als canvis en la biodiversitat estructural i compositiva dels boscos de sureres i dels paisatges agrícoles del nord–oest del Marroc. La ubicació geogràfica del Marroc proporciona una biodiversitat excepcional. Aquest estudi té com a objectiu omplir els buits sobre la biodiversitat dels escarabats al nord–oest del Marroc, i per fer–ho es van explorar els boscos de sureres *Quercus suber* L. de Larraix i la plana de Gharb, durant dos anys consecutius (2021 i 2022), a través d'un inventari d'escarabats. Els resultats obtinguts van permetre identificar 5.405 espècimens pertanyents a 246 espècies i 39 famílies. En aquest estudi es van identificar tres tendències: 1) la família Tenebrionidae, amb una afinitat distintiva pels climes mediterranis, va ser la més diversa quant a espècies; 2) es van trobar pocs escarabats saproxilòfags, xilòfags i copròfags; i 3) el bosc d'alzines sureres de Larraix exerceix un paper ecològic vital a la zona, ja que la biodiversitat d'escarabats i els seus grups funcionals és molt més alta als sectors forestals que a les àrees agrícoles properes.

Dades publicades a GBIF (DOI: 10.15470/kklmel).

Paraules clau: Escarabats, Bosc de sureres de Larraix, Sector agrícola, Nord–oest, Marroc

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Introduction

Oak woodlands provide shelter and food for diverse entomofauna (Pujade–Villar et al., 2010; Sallé et al., 2021). Despite some exceptional cases of destructive insect outbreaks, the influence of insects is most often positive and even essential to maintain the balance of the forest (Nicolas, 2009). Abundance and species diversity of insects contributes to the vitality and stability of forest ecosystems (Daily et al., 2000). The multiple ecosystem services that insects provide include nutrient cycling, pollination, and biological regulation of pests (Elizalde et al., 2020).

The north–western region of Morocco, which includes the Larache cork oak *Quercus suber* L. forest and the Gharb Plain, is an essential part of the oak woodlands of the Atlantic coastal plain. This forest is currently experiencing alarming deterioration of its natural forest stands due to a combination of climatic and anthropogenic factors such as intensive agriculture, overgrazing, industrial forest plantations, and increasing urbanization. This degradation of the woody vegetation cover threatens faunal biodiversity and numerous ecosystem services in the area (Sánchez–Bayo and Wyckhuys, 2019; Staab et al., 2023).

In the context of global change, insect conservation is of paramount importance. These invertebrates act as sensitive bioindicators of ecosystem quality and the impact of human intervention on forests (Dubucq, 2020; Sallé et al., 2021). Beetles (Coleoptera) are substantial tools for monitoring terrestrial environmental change because of their high systematic, ecological, and morphological diversity in terrestrial environments (Lindenmayer et al., 2000; Ghannem et al., 2017). However, while studies have been undertaken to examine saproxylic beetles in Mediterranean forests (see Ricarte et al., 2009; Micó et al., 2013), information on beetle biodiversity in the southern Mediterranean region remains insufficient.

Few studies in Morocco have analysed terrestrial beetle response to forest disturbances (although see Baraud, 1985; Villemant and Fraval, 1993), and the few that do exist to date have concentrated mainly on relatively well–conserved environments (Arahou, 2008; Mouna, 2013; Benyahia et al., 2015). One recent study highlighted the diversity of beetles in undisturbed and cultivated natural areas (El Harche et al., 2022) but knowledge is lacking regarding the current state and responses of southern Mediterranean beetle species and functional groups to anthropogenic disturbances. As a result, approaches to inform decision–makers regarding conservation decisions for this insect community are lacking. Here, over a two–year period, we analysed the role of landscape composition on the spatial distribution and functional diversity of beetles in the cork oak forests of Larache and the agricultural lands of the Gharb plain in the north–western region of Morocco.

Material and methods

Study area

The study area is situated in the northwest of Morocco (fig. 1) and is a mosaic of large remnant forest and annual crop fields. The cork oak forest in Larache is continuous with the Maamora forest of Rabat, part of the cork oak forest of the Atlantic coastal plain, and it has a sub–humid thermo Mediterranean climatic stage with mild to temperate winters (Boudy, 1952; Ballouche, 2013). The main forest area has been largely opened up by deforestation and grazing and locally replaced by reforestation with eucalyptus, pine, and acacia. The soil in the area is generally sandy and suitable for crops (cereals, peanuts, vegetables, citrus fruits) (Sauvage, 1961). The Gharb plain is a major agricultural area in Morocco and is irrigated by the Oued Sebou river. Herein, crops including tomatoes, onions, zucchini, carrots, bell peppers, oranges, lemons, and oilseeds are cultivated for both export and local consumption (HCEFLCD, 2013; Chbika, 2021).

Description of the sampled stations

We selected five stations in five municipalities in the northwest of Morocco: three stations in the forest sector (Ezzouada S1, Ouled Hammou S2, and Rissana S3) located in the cork oak forest of Larache and two stations in the agricultural sector (Moulay Bousselham S4 and Souk Larbaa S5) situated in the Gharb Plain. These stations were selected based on

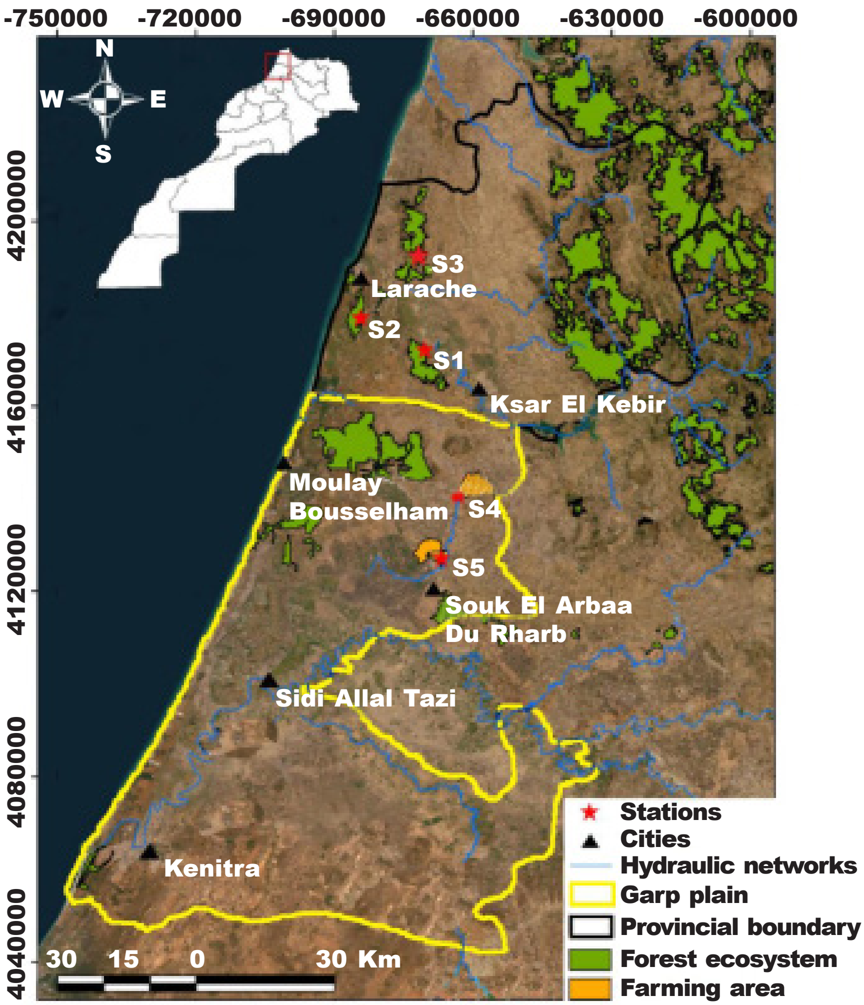

Fig. 1. Study area and locations of the sampling sites (S1–S5).

Fig. 1. Área de estudio y las ubicaciones de los puntos de muestreo (S1–S5).

the type of vegetation cover (table 1). The agricultural lands in our study have been used for several decades for farming purposes. Typical treatments include pesticides targeting specific pests and tillage practices for soil management. Some farms focus on monocultures.

Sampling methods

Four trapping systems were installed in each of the five stations during the daytime. Coloured pan traps (yellow, white, orange, and blue) were installed to capture flower–visiting beetles (Nageleisen and Bouget, 2009). These pan traps had a diameter of 15 cm and a height of 13 cm. Each pan trap was filled halfway with a water (60 %), detergent (20 %),

Table 1. Satellite coordinates and description of the various stations sampled.

Tabla 1. Coordenadas geográficas y descripción de las diferentes zonas de muestreo.

Stations/ Municipalities	**Geographical coordinates**	**Description**
Forested areas		
S1 (Ezzouada)	35.055000 -6.036417	Cork oak forest *Quercus suber* with a relatively dense undergrowth mainly composed of rockrose *Cistus salviifolius*, *C. creticus* and sunrose *Helianthemum lavandulifolium*.
S2 (Ouled Hammou)	35.111667 -6.147250	Open cork oak forest located near a forest track and a persimmon orchard *Diospyros blancoi*.
S3 (Rissana)	35.211964 -6.032728	Edge of a dense cork oak forest used as a corridor, characterized by an abundance of lowering plants including *Trifolium resupinatum*, *Ranunculus millefoliatus*, *Centaurea pullata*, *Scolymus hispanicus*, *Echium plantagineum*, *Lotus hispidus*, and *Tolpis barbata*.
Agricultural areas		
S4 (Moulay Bousselham)	34.898356 -6.210567	Farm specializing in the production of blueberries *Vaccinium koreanum* and watermelons *Citrullus lanatus* with pesticides and plowing in use.
S5 (Souk Larbaa)	34.699897 -6.042158	Seasonal monoculture field dominated by the umbellifer *Ammi majus*.

and salt (20 %) mixture and fixed 1 m above the ground. Barber pitfalls were used to intercept species active on the ground (Nageleisen and Bouget, 2009). Barber pitfalls were constructed using plastic cups with a top diameter of 60 mm. They were filled with water (60 %), detergent (20 %), and salt (20 %) and buried flush with the ground. Additionally, a Malaise trap was used to capture specific flying beetles (Ulyshen et al., 2005; Sheikh et al., 2016). The Malaise traps were constructed of black and white material and handmade. Each trap measured approximately 1.5 m in height, 1.2 m in width, and 1.5 m in length. The design of the trap is shown in the figure 2.

The traps were installed using stakes driven into the ground and secured with nets. The collection cups contained a solution of 50 % ethanol, 5 % detergent, and 45 % water to preserve the captured specimens. At each station, 11 traps (six Barber pitfall, four pan traps, and one Malaise trap) were installed and spaced at a distance of 15 to 20 m apart.

Alongside the passive collection techniques described above, we conducted active searching for the direct capture of individuals encountered along straight transects (1 m x 100 m) in the sampled sites. We standardized our active searches by making consistent

Fig. 2. Installation and anchoring of the Malaise trap.

Fig. 2. Instalación y anclaje de la trampa Malaise.

efforts at each site. Each research session was conducted over a defined period of 8 hours within one day, with a uniform number of three researchers. Trap contents were collected every 20 days over 7 months (April–October) over two consecutive years (2021–2022).

Following each sampling mission, the collected insects were individually placed in plastic vials, labelled, and preserved in 70 % ethyl alcohol. The collected specimens were examined in the laboratory, counted, and identified up to the species and/or genus level using a binocular loupe 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). To determine the functional group for each species, we used a combination of methods that included direct observations of feeding behaviour and a review of existing scientific literature (Velle, 2004; Carpaneto et al., 2015). Each species was classified according to specific criteria such as their primary diet and also by their ecological roles (phytophagous, coprophagous, mycophagous, xylophagous, sapro–xylophagous, necrophagous, flower visitors and predators). The determination of species and their classification into functional groups were validated by Fabien Soldati.

Data analysis

To examine the composition and structure of the beetle community, we used various indices to compare communities at the sampled locations. First, species richness (S) was calculated as the total number of species present at a station (Ramade, 2003). We then calculated the relative abundance expressed as a percentage (RA %) (Frontier, 1983), which corresponds to the number of individuals of a species (ni) divided by the total number of individuals (N) and formulated as follows:

$$RA\ \% = (ni/N)*100$$

Functional diversity was estimated considering the number of species within each functional group. The percentage that each functional group contributed to the total diversity was calculated using the following formula:

$$\text{Percentage contribution (\%)} = (si/S)*100$$

where (si) represents the number of species in a specific functional group, and S is the total number of species identified across all functional groups. This method highlights the distribution of ecological roles within the studied communities, enabling comparisons between habitats. Previous studies have shown that this approach provides critical insight into the functional structure of communities in various ecological contexts (Petchey and Gaston, 2006; Mason et al., 2005).

We also calculated the percentage relative abundance of functional groups in order to reflect the proportion of individuals belonging to each functional group (ni) relative to the total number of individuals collected across all functional groups (N), using the formula:

$$RA\ \%\ \text{(functional group)} = (ni/N)*100$$

This metric helps to understand the relative importance of each functional group within the community (Hoffmann and Andersen, 2003).

The Shannon–Weaver diversity index (H') was used to assess species diversity (Dajoz, 2008), and calculated using the formula:

$$H' = -\Sigma\ (ni/N)\log 2\ (ni/N)$$

Additionally, the Simpson index (D) was used to measure the probability that two randomly chosen individuals belong to the same species in a population (Blondel, 1975), calculated by the formula:

$$D = \Sigma(ni(ni-1)/(N(N-1)))$$

Evenness (E), assessed through the Pielou's evenness index, represents the ratio between observed diversity (H') and theoretical maximum diversity (H' max), where H' max is calculated as log2(S) (Blondel, 1975).

Results

We collected a total of 5,405 individuals from 246 species belonging to 39 families (see also dataset published through GBIF, DOI: 10.15470/kklmel).

Results showed Scarabaeidae, Curculionidae, Carabidae, and Tenebrionidae were the most well represented families (fig. 3), with 25, 24, 23, and 21 species respectively, followed by Coccinellidae (17), Chrysomelidae (14), and Cerambycidae (10). The other thirty–two families contained less than ten species (annex).

Individuals of Tenebrionidae represented 49.10 % of the total number of individuals captured (2,654), followed by Melyridae (668; 12.35 %), then the Scarabaeidae (298; 5.51 %). The Oedemeridae (257; 4.75 %), and Mordellidae (225; 4.16 %). The other families generally showed a low percentage, not exceeding 4 % (fig. 4).

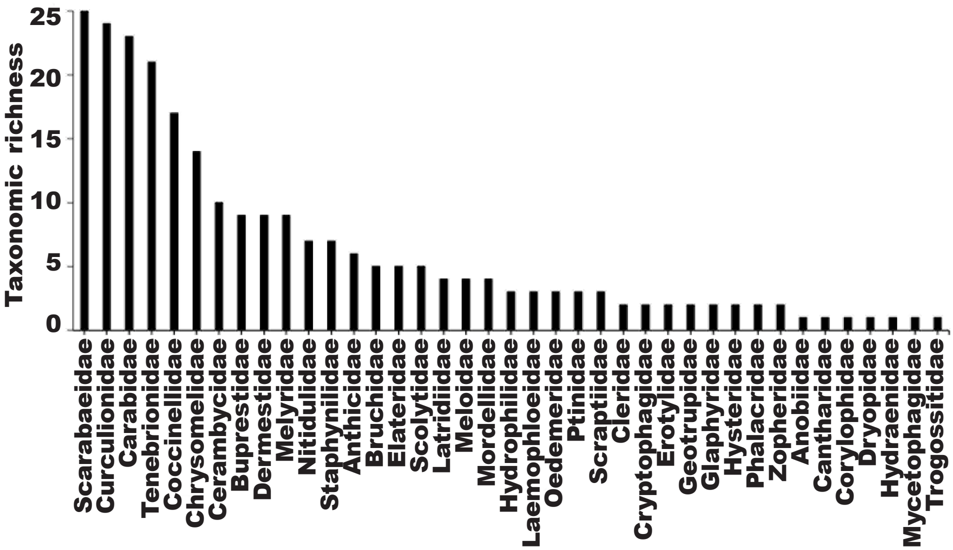

Fig. 3. Taxonomic richness per beetle family captured in the northwest region of Morocco.

Fig. 3. Riqueza taxonómica por familia de escarabajos capturados en la región noroeste de Marruecos.

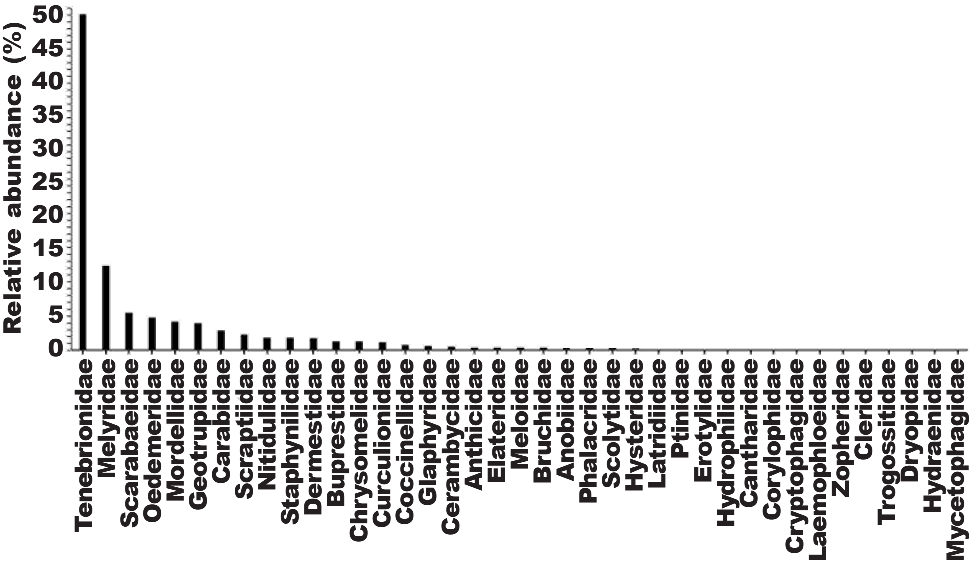

Fig. 4. Relative abundance profile of different families of beetles captured in northwestern Morocco.

Fig. 4. Perfil de abundancia de diferentes familias de escarabajos capturados en el noroeste de Marruecos.

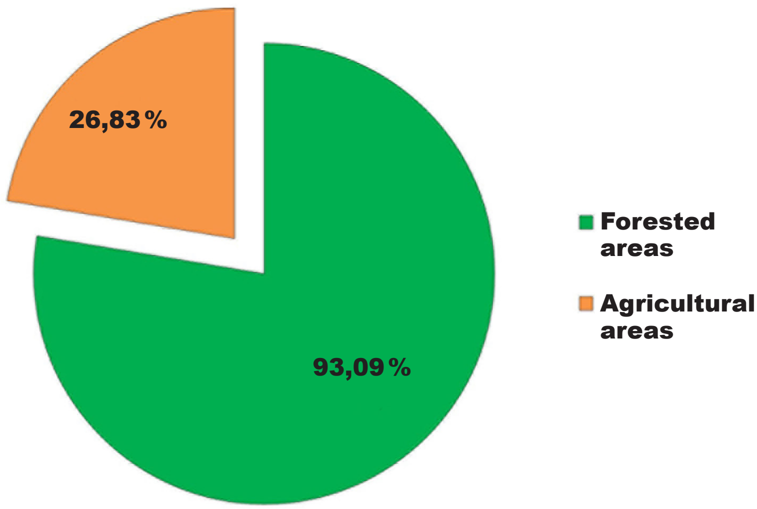

Fig. 5. Percentage (%) of beetle diversity in forested and agricultural areas in the north–west of Morocco.

Fig. 5. Porcentaje (%) de diversidad de escarabajos en áreas forestales y agrícolas en el noroeste de Marruecos.

The forested areas contained higher beetle diversity (93.09 % and 229 species) while agricultural areas showed lower diversity, with only 66 species (26.83 %) (fig. 5).

The forested sectors also showed higher functional diversity than the agricultural sector (fig. 6). Functional diversity within the forested sectors was divided between flower visitors (24.79 % of the species found), predators (20.73 %) and phytophagous species (19.51 %). The other guilds held less than 10 % of the functional diversity in forested sectors, with saprophagous species representing 9.34 % of the total species recorded, mycophagous 5.28 %, xylophagous 4.06 %, coprophagous 3.65 %, sapro–xylophagous 3.65 %, and necrophagous 2.84 %.

Relative abundance within functional groups (fig. 7) was highest in the forest sector; 46.51 % of the 5,405 total individuals trapped were saprophagous and found in the forest sector, while less than five percent of the total individuals captured were saprophagous and captured in the agricultural sector.

Ecological indices Shannon (H'), Simpson (D), and Evenness (E) were calculated at each sampling stations (table 2).

The Shannon diversity index H' varied widely between stations, ranging from 4.98 to 2.34. The highest Shannon indices were found in the forest area S1 (4.12) and S2 (4.06). Low values were observed in S4 (2.34) and S5 (2.96) in agricultural lands. S3 (a forested sector) exhibited the highest Shannon index (4.98) and harboured the highest species richness (173 species). Simpson's Index (D) values were lower in forest setting (S1–S3) than in agricultural settings (S4–S5). Evenness index values (E) were high across S1 (0.61), S2 (0.67) and S3 (0.67). This suggests a fairly balanced distribution of individuals between species in sites S1, S2, and S3, while a less equitable distribution was observed in S4 and S5 (table 2).

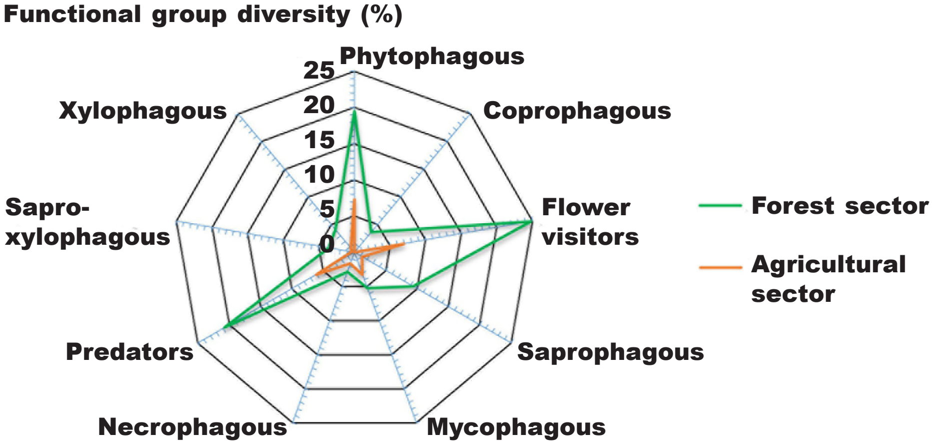

Fig. 6. Diagram illustrating the functional group diversity observed during our study.

Fig. 6. Diagrama que ilustra la diversidad de los grupos funcionales durante el presente estudio.

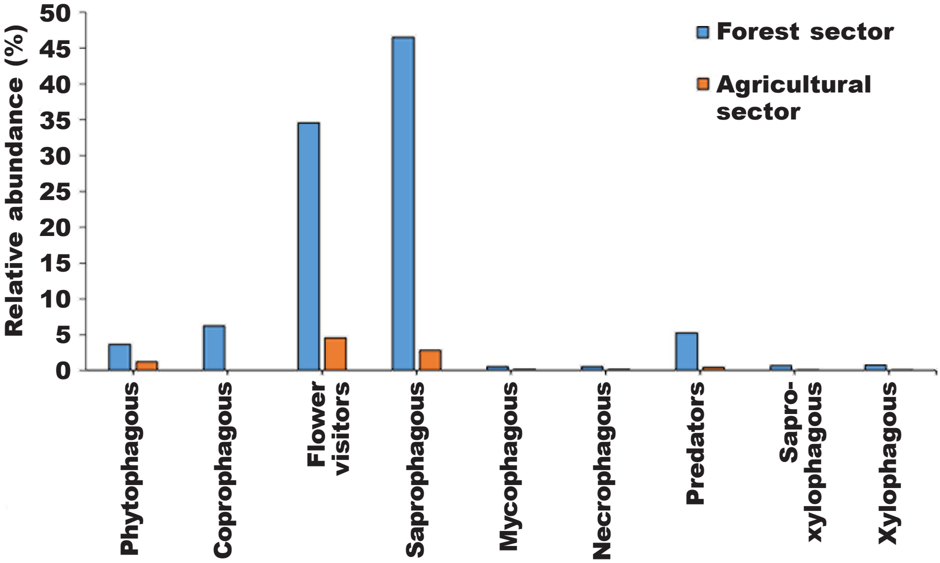

Fig. 7. Percentage of relative abundance of functional groups of beetle within forest and agricultural sectors.

Fig. 7. Porcentaje de abundancia relativa de grupos funcionales de escarabajos en áreas forestales y agrícolas.

Table 2. Ecological indices of diversity and evenness to differentiate the five sampling stations. H', Shannon index; Hmax, maximum diversity; E, evenness index; S, species richness; D, Simpson index.

Tabla 2. Índices ecológicos tradicionales (diversidad y uniformidad) para el análisis de la biocenosis de las estaciones muestreadas. H', índice de Shannon; Hmax, diversidad máxima; E, Índice de equitatividad; S, riqueza de especies; D, índice de Simpson.

Station	H'	Hmax	E	S	D
S1	4.12	6.70	0.61	104	0.09
S2	4.06	6.02	0.67	65	0.12
S3	4.98	7.43	0.67	173	0.09
S4	2.34	4.45	0.52	22	0.40
S5	2.96	5.72	0.51	53	0.24

Discussion

Three trends were evident in our study: (1) Tenebrionidae, a family with a distinct affinity to Mediterranean climates, was the most species rich family in our study; (2) few sapro–xylophagous, xylophagous, and coprophagous beetles were found in the study; and (3) forested sites had more functional and species diversity than farming sites, a finding supported by at least one other Mediterranean study. The diversity of the forested sites underlines the ecological importance of oak forests in Larache. The composition and behavioural responses of beetle communities is strongly associated with their feeding habitats (Seibold et al., 2019).

In our study, Tenebrionidae was the most abundant family, constituting 49.10 % of the individuals collected (2,654), and all Tenebrionidae species found in our study are known to be saprophagous (annex). Saprophagous insects play a crucial role in the decomposition of organic matter and the enhancement of soil fertility (Coulis et al., 2015). Tenebrionidae predominance has been linked to the presence of a high rate of decomposing organic matter, which is essential for feeding and the completion of its life cycle and to its long period of activity, which can sometimes last for two or three seasons per year (Seibold et al., 2019). Furthermore, Tenebrionidae species are known for their adaptations to hot and dry climates, such as Mediterranean climates (Fattorini et al., 2014). Our results support by previous work showing that Morocco has a very high rate of Tenebrionidae endemism (Chavanon, 2003; Benyahia et al., 2015).

Few sapro–xylophagous, xylophagous and coprophagous beetles were found in our study. Saprox–ylophagous species had a low relative abundance (3.65 %) and functional species diversity (0.64 %). We found that xylophagous species were also poorly represented in terms of relative abundance (0.77 %) and functional species diversity (4.06 %). Saproxylic beetles are typically associated with the decomposition of dead wood, and the survival and life cycle of this species depend closely on the availability of cavities and crevices in old trees, which provide essential refuge and breeding sites (Fayt et al., 2006; Della Rocca et al., 2022). It is possible our study sites did not have enough dead wood or old trees to support robust saproxylic insect populations. However, the limited occurrence of sapro–xylophagous and xylophagous beetles may be attributed to the sampling methods used because these families are commonly collected using flight interception traps (Bouget et al., 2008; Burner et al., 2022), techniques that we did not use in this study.

Coprophagous fauna were also poorly represented in our findings, representing only 6.21 % of total abundance and only 3.65 % of functional species diversity. Coprophagous beetles play a crucial role in improving soil fertility, but their activity has been shown to decrease during dry periods in Morocco (Lumaret, 1983). This low representation may be attributed to the limited spatial and temporal availability of excrement.

We observed greater species diversity (229 species) in forested areas (forest and edge) than in agricultural areas. This richness was higher than that observed in other oak forests, such as in Algeria (Ganaoui et al., 2020), where 76 species distributed across 61 genera and 21 beetle families were found. We observed some similarities in families and genera in our study and the Algerian study. Some species composition differences may vary due to variances in sampling methods as in the Algerian study only pitfall traps and interception traps were used, while we used pitfall traps, Malaise traps, and active searching. It is probable that the similar climate, habitat type, and resource availability in Algeria and Morocco influence beetle biodiversity in these two regions.

In the agricultural areas, the beetle community tends to be taxonomically less species diversity (26.83 %, 66 species) than the community in forested areas (93.09 %, 229 species), with a decrease in abundance in all functional groups). Our results are consistent with the findings of El Harche et al (2022), which suggest that highly disturbed habitats tend to have low diversity. Factors such as intensive insecticide use, mowing, and tillage, are known to affect arthropod communities and reduce both their abundance and diversity (Seibold et al., 2019). Harmful agricultural practices cause disturbances in beetle assemblages and result in significant damage to species diversity, limiting their ability to reproduce and move (Foley et al., 2005; Serrano et al., 2005; El Harche et al., 2022). The lower species diversity may indicate a potential ecological imbalance in S4 and S5. It is important to note, however, that only two agricultural sites were sampled but three forested sites were sampled. Our general conclusions regarding differences in diversity and abundance may therefore be skewed.

Conclusion

We sampled beetle diversity in agricultural and forested areas in Northwest of Morocco in 2021 and 2022. Our results indicate that this forest type hosts a remarkable diversity of beetles. The agricultural sector hosted lower beetle diversity. To support conservation of biodiversity in Morocco, the cork oak forest in Larache deserves more attention from both forest managers and researchers.

Acknowledgments

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Annex. Beetle species collected from five sites in the northwest region of Morocco. List of functional groups of each species and their relative abundance (RA %) per site: FG, feeding groups (adults) (X, xylophagous; S, saprophagous; Ph, phytophagous; F, flower visitors; Pr, predators; Sx, sapro–xylophagous; M, mycophagous; C, coprophagous; N, necrophagous); ni, number of individuals of a given species; N, total number of individuals.

Anexo. Especies de escarabajos recolectadas en cinco sitios en la región noroeste de Marruecos. Se enumeran los grupos funcionales de cada especie, así como su abundancia relativa (RA %) por sitio: FG, grupos tróficos (adultos) (X, xilófagos; S, saprófagos; Ph, fitófagos; F, visitantes florales; Pr, predadores; Sx, saproxilófagos; M, micófagos; C, coprófagos; N, necrófagos); ni, número de individuos de una especie determinada; N, número total de individuo.

		Stations									
		S1		S2		S3		S4		S5	
Taxon	**FG**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**
Anobiidae		4	0.16			13	0.68			1	0.27
Stegobium paniceum (Linnaeus, 1758)	X	4	0.16			13	0.68			1	0.27
Anthicidae		1	0.04			19	1.00			2	0.54
Anthicus cervinus (LaFerte-Senectere, 1848)	S									1	0.27
Clavicomus versicolor (Kiesenwetter, 1866)	S									1	0.27
Hirticollis quadriguttatus (Rossi, 1792)	S					9	0.47				
Microhoria sp.	S	1	0.04								
Omonadus bifasciatus (Rossi, 1792)	S					9	0.47				
Omonadus floralis (Linnaeus, 1758)	S					1	0.05				
Bruchidae		8	0.31			8	0.42	1	0.78	4	1.08
Bruchidius biguttatus (Olivier, 1795)	Ph	2	0.08							1	0.27
Bruchidius bimaculatus (Olivier, 1795)	Ph					1	0.05				
Bruchidius foveolatus (Gyllenhal, 1833)	Ph	4	0.16			3	0.16	1	0.78	1	0.27
Bruchidius sp.	Ph	2	0.08			2	0.11			2	0.54
Bruchidius sp.	Ph					2	0.11				
Buprestidae		13	0.51	5	1.09	53	2.79			2	0.54
Acmaeoderella adsperula (Illiger, 1803)	F	4	0.16			4	0.21				
Acmaeoderella discoida (Fabricius, 1787)	F					1	0.05				
Acmaeoderella lanuginosa (Gyllenhall, 1817)	F	1	0.04			21	1.11			2	0.54
Agrilus biguttatus (Fabricius, 1777)	F					1	0.05				
Agrilus graminis (Kiesewetter, 1857)	F			3	0.66						
Anthaxia millefolii (Fabricius, 1801)	F	3	0.12	1	0.22	6	0.32				
Anthaxia scutellaris (Gené, 1839)	F			1	0.22	7	0.37				
Anthaxia umbellatarum (Fabricius, 1787)	F	1	0.04			13	0.68				
Habroloma triangulare (Lacordaire, 1835)	F	4	0.16								
Cantharidae						3	0.16				
Rhagonycha sp.	F					3	0.16				
Carabidae		40	1.57	34	7.44	72	3.79			11	2.96
Acupalpus brunnipes (Sturm, 1825)	Pr					2	0.11				
Acupalpus sp.	Pr					2	0.11			2	0.54
Agonum emarginatum (Gyllenhal, 1827)	Pr					8	0.42				
Bembidion biguttatum (Fabricius, 1779)	Pr					1	0.05				
Bembidion bipunctatum (Linnaeus, 1760)	Pr					1	0.05			2	0.54
Bradycellus verbasci (Duftschmid, 1812)	Pr					2	0.11			1	0.27
Carterus rotundicollis (Rambur, 1837)	Pr					1	0.05				
Cicindela maroccana (Fabricius, 1801)	Pr	1	0.04								
Cymindis lineola (L. Dufour, 1820)	Pr	1	0.04	1	0.22						
Cymindis platicollis (Say, 1823)	Pr			2	0.44						
Distichus planus (Bonelli, 1813)	Pr									1	0.27
Harpalus attenuatus (Stephens, 1828)	Pr					9	0.47				
Microlestes abeillei (Brisout de Barneville, 1885)	Pr					4	0.21			1	0.27
Ophonus ardosiacus (Lutshnik, 1922)	Pr	1	0.04			1	0.05			1	0.27

Annex. (Cont.)

		Stations									
		S1		S2		S3		S4		S5	
Taxon	**FG**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**
Ophonus subquadratus (Dejean, 1829)	Pr					8	0.42			1	0.27
Paradromius linearis (Olivier, 1795)	Pr					1	0.05				
Philorhizus notatus (Stephens, 1827)	Pr	1	0.04							2	0.54
Pterostichus elongatus (Duftschmid, 1812)	Pr	27	1.06	31	6.78	9	0.47				
Scarites terricola terricola (Bonelli, 1813)	Pr	7	0.27								
Singilis soror soror (Rambur, 1837)	Pr	2	0.08								
Stenolophus abdominalis abdominalis (Gene, 1836)	Pr					14	0.74				
Stenolophus teutonus (Schrank, 1781)	Pr					6	0.32				
Syntomus foveatus (Geoffroy in Fourcroy, 1785)	Pr				3	0.15					
Cerambycidae		5	0.20	2	0.44	18	0.95	1	0.78	2	0.54
Agapanthia irrorata (Fabricius, 1787)	F					1	0.05				
Alocerus moesiacus (Frivaldszky, 1837)	Sx			2	0.44	1	0.05				
Certallum ebulinum (Linné, 1767)	F					2	0.11				
Chlorophorus favieri (Farimaire, 1873)	F					1	0.05				
Opsilia coerulescens (Scopoli, 1763)	F					1	0.05			1	0.27
Oxypleurus nodieri (Mulsant, 1839)	Sx					1	0.05				
Phoracantha recurva (Newman, 1840)	Sx							1	0.78		
Stenurella approximans (Rosenhauer, 1856)	F	3	0.12			4	0.21			1	0.27
Stictoleptura fontenayi (Mulsant et Rey, 1839)	F	1	0.04								
Trichoferus ilicis (Sama, 1987)	Sx	1	0.04			7	0.37				
Chrysomelidae		6	0.24	18	3.94	43	2.26			3	0.81
Aphthona euphorbiae (Schrank, 1781)	Ph					1	0.05				
Cassida vittata (Villers, 1789)	Ph					23	1.21			1	0.27
Cassida sp.	Ph	1	0.04	1	0.22	2	0.11				
Chrysolina bankii (Fabricius, 1775)	Ph	1	0.04								
Chrysolina diluta (Germar, 1823)	Ph			1	0.22						
Cryptocephalus fulvus (Goeze, 1777)	Ph	1	0.04	1	0.22						
Cryptocephalus numidicus (Bourdonné, 1876)	Ph					1	0.05				
Lachnaia sp.	Ph	1	0.04								
Longitarsus aeneus (Kutschera, 1862)	Ph	1	0.04	2	0.44	7	0.37			1	0.27
Longitarsus ochroleucus (Marsham, 1802)	Ph	1	0.04	13	2.84	2	0.11			1	0.27
Luperus sp.	Ph					1	0.05				
Oulema melanopus (Linnaeus, 1758)	Ph					1	0.05				
Phyllotreta sp.	Ph					3	0.16				
Psylliodes cuprea (Koch, 1803)	Ph					2	0.11				
Cleridae						1	0.05			1	0.27
Tilloidea sp.	Sx					1	0.05				
Trichodes leucopsideus (Olivier, 1800)	F									1	0.27
Coccinellidae		10	0.39	21	4.60	7	0.37	1	0.78	4	1.08
Adalia decempunctata (Linnaeus, 1758)	Pr			1	0.22						
Chilocorus bipustulatus (Linnaeus, 1758)	Pr			1	0.22						
Coccinella septempunctata (Linnaeus, 1758)	Pr			1	0.22						
Exochomus sp.	Pr			1	0.22						
Oenopia conglobata (Linnaeus, 1758)	Pr	1	0.04	3	0.66	1	0.05			1	0.27
Oenopia lyncea (Olivier, 1808)	Pr	3	0.12								
Platynaspis luteorubra (Goeze, 1777)	Pr					1	0.05				
Rhyzobius litura (Fabricius 1787)	Pr	1	0.04	2	0.44			1	0.78		
Rhyzobius lophantae (Blaisdell, 1892)	Pr			1	0.22	1	0.05				
Rodolia cardinalis (Mulsant, 1850)	Pr	1	0.04	1	0.22	1	0.05				

Annex. (Cont.)

		Stations									
		S1		S2		S3		S4		S5	
Taxon	**FG**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**
Scymnus abietis (Paykull, 1798)	Pr			1	0.22						
Scymnus apetzi (Mulsant, 1846)	Pr			3	0.66	1	0.05				
Scymnus impexus (Mulsant, 1850)	Pr			4	0.88						
Scymnus interruptus (Goeze, 1777)	Pr			1	0.22	1	0.05				
Scymnus subvillosus (Goeze, 1777)	Pr			1	0.22						
Scymnus suturalis (Westman in Thunberg, 1795)	Pr					1	0.05			2	0.54
Stethorus punctillum (Weise, 1891)	Pr	4	0.16							1	0.27
Corylophidae						3	0.16				
Arthrolips convexiuscula (Motschulsky, 1849)	M					3	0.16				
Cryptophagidae						1	0.05			2	0.54
Cryptophagus sp.	M					1	0.05			1	0.27
Henoticus sp.	M									1	0.27
Curculionidae		22	0.86	5	1.09	30	1.58	2	1.56	6	1.61
Apion frumentarium (Walton, 1844)	Ph	1	0.04			2	0.11				
Bagous sp.	Ph					1	0.05				
Brachyderes incanus (Linné, 1758)	Ph	3	0.12	1	0.22						
Brachyderes pubescens (Boheman, 1833)	Ph	3	0.12	1	0.22	1	0.05				
Brachytemnus porcatus (Germar, 1823)	X	3	0.12			1	0.05				
Ceutorhynchus pallidactylus (Marsham, 1802)	Ph	1	0.04								
Coeliodes ruber (T.Marsham, 1802)	Ph					2	0.11			1	0.27
Curculio pyrrhoceras (T.Marsham, 1802)	Ph	4	0.16								
Hemitrichapion reflexum (Gyllenhal, 1833)	Ph	3	0.12			3	0.16				
Lixus juncii (Boheman, 1835)	Ph	1	0.04			4	0.21				
Malvapion malvae (Fabricius, 1775)	Ph							1	0.78		
Microplontus rugulosus (J.F.W.Herbst, 1795)	Ph					1	0.05				
Orchestes irroratus (Kiesenwetter, 1852)	Ph	2	0.08								
Orchestes sp.	Ph							1	0.78		
Rhinocyllus conicus (Froelich, 1792)	Ph									2	0.54
Sitona callosus (Gyllenhal, 1834)	Ph			1	0.22						
Sitona lineatus (Linnaeus, 1758)	Ph					5	0.26				
Sitona lineellus (Bonsdorff, 1785)	Ph					2	0.11				
Sitona longulus (Gyllenhal, 1834)	Ph			1	0.22	1	0.05				
Sitona sp.	Ph	1	0.04			1	0.05				
Sitophilus oryzae (Linnaeus, 1763)	Ph									1	0.27
Smicronyx sp.	Ph									1	0.27
Tychius cuprifer (Panzer, 1799)	Ph			1	0.22						
Tychius pusillus (Germar, 1842)	Ph					6	0.32			1	0.27
Dermestidae		19	0.75	5	1.09	74	3.89				
Anthrenus flavipes (LeConte, 1854)	F					4	0.21				
Anthrenus fuscus (Olivier, 1790)	F	1	0.04	1	0.22	6	0.32				
Anthrenus museorum (Linnaeus, 1761)	F					1	0.05				
Anthrenus pimpinellae (Fabricius, 1775)	F					1	0.05				
Anthrenus sp.	F	3	0.12			11	0.58				
Attagenus bifasciatus (Fabricius, 1787)	F	7	0.27	1	0.22	43	2.26				
Dermestes frischii (Kugelann, 1792)	N	4	0.16	3	0.66	6	0.32				
Orphilus niger (Rossi, 1790)	N					1	0.05				
Trogoderma granarium (Everts, 1898)	F	4	0.16			1	0.05				
Dryopidae						1	0.05				
Dryops luridus (Erichson, 1847)	Ph					1	0.05				

Annex. (Cont.)

		Stations									
		S1		S2		S3		S4		S5	
Taxon	**FG**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**
Elateridae		3	0.12	5	1.09	14	0.74				
Athous sp.	Sx	1	0.04			3	0.16				
Cardiophorus rufipes (Buysson, 1902)	Sx	2	0.08	5	1.09	6	0.32				
Cardiophorus sp.	Sx					1	0.05				
Conoderus bellus (Say, 1824)	Sx					1	0.05				
Drasterius bimaculatus (Rossi, 1790)	Sx					3	0.16				
Erotylidae						1	0.05	1	0.78	2	0.54
Cryptophilus integer (Heer, 1841)	M							1	0.78	1	0.27
Triplax lacordairei (Crotch, 1870)	M					1	0.05			1	0.27
Geotrupidae		131	5.14	66	14.44	19	1.00				
Thorectes distinctus (Marseul, 1878)	C	131	5.14	65	14.22	19	1.00				
Typhaeus typhoeus (Linnaeus, 1758)	C			1	0.22						
Glaphyridae		1	0.04			20	1.05	13	10.16		
Anthypna meles (Fabricius, 1792).	F	1	0.04			1	0.05				
Eulasia goudoti (Laporte, 1840)	F					19	1	13	10.16		
Histeridae		8	0.31			5	0.26			1	0.27
Hypocaccus rugiceps (Duftschmid, 1805)	N					4	0.21			1	0.27
Saprinus proximus simimmimis (Wollaston, 1865)	N	8	0.31			1	0.05				
Hydraenidae						1	0.22				
Ochthebius bicolon (Germar, 1823)	M					1	0.22				
Hydrophilidae						4	0.21				
Cercyon obsoletus (Gyllenhal, 1808)	Pr					1	0.05				
Cercyon sp.	Pr					1	0.05				
Sphaeridium scarabaeoides (Linnaeus, 1758)	Pr					2	0.11				
Laemophloeidae				1	0.22	2	0.11				
Laemophloeus monilis (Fabricius, 1787)	M			1	0.22						
Laemophloeus muticus (Fabricius, 1781)	M					1	0.05				
Leptophloeus sp.	M					1	0.05				
Latridiidae		1	0.04			3	0.16			2	0.54
Corticarina cavicollis (Mannerheim, 1844)	M									1	0.27
Corticarina curta (Wollaston, 1854)	M					1	0.05			1	0.27
Enicmus transversus (Olivier, 1790)	M	1	0.04								
Stephostethus productus (Rosenhauer, 1856)	M					2	0.11				
Meloidae		21	0.82			1	0.05				
Berberomeloe majalis (Linnaeus, 1758)	F	1	0.04								
Croscherichia paykulli (Billberg, 1813)	F	1	0.04								
Hycleus rufipalpis (Escalera, 1909)	F	19	0.75								
Mylabris variabilis (Pallas, 1781)	F					1	0.05				
Melyridae		189	7.42	23	5.03	349	18.37	86	67.19	21	5.65
Aplocnemus sp.	F					1	0.05				
Aplocnemus virens (Suffrian, 1843)	F	1	0.04			6	0.32				
Clanoptilus sp.	F	1	0.04								
Colotes javeti (Jacquelin du Val, 1852)	F	1	0.04							1	0.27
Danacea sp.	F					1	0.05	80	62.5	20	5.38
Dasytes nigroaeneus (Küster, 1850)	F	89	3.49	14	3.06	237	12.47	6	4.69		
Dasytes terminalis (Jacquelin du Val, 1863)	F	90	3.53	5	1.09	102	5.37				
Psilothrix viridicoerulea (Geoffroy, 1758)	F	1	0.04			2	0.11				
Troglops furcatus (Perrin, 1885)	F	6	0.24	4	0.88						

Annex. (Cont.)

		Stations									
		S1		S2		S3		S4		S5	
Taxon	**FG**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**
Mordellidae		4	0.16	1	0.22	212	11.16	4	3.13	4	1.08
Mediimorda bipunctata (Germar, 1827)	F			1	0.22	44	2.32	3	2.34	2	0.54
Mordella aculeata (Linnaeus, 1758)	F	3	0.12			5	0.26			2	0.54
Mordellistena sp.	F					1	0.05	1	0.78		
Variimorda villosa (Schrank von Paula, 1781)	F	1	0.04			162	8.53				
Mycetophagidae										1	0.27
Litargus balteatus (LeConte, 1856)	M									1	0.27
Nitidulidae		17	0.67	4	0.88	29	1.53	6	4.69	43	11.56
Acanthogethes sp. (Olivier, 1790)	Ph	2	0.08			8	0.42				
Carpophilus hemipterus (Linnaeus, 1758)	Ph			1	0.22	1	0.05				
Epuraea latipes (Grouvelle, 1896)	Ph					2	0.11			1	0.27
Meligethes aeneus (Fabricius, 1775)	Ph	9	0.35	2	0.44	10	0.53	4	3.13	40	10.75
Meligethes viridescens (Fabricius, 1787)	Ph	3	0.12	1	0.22	4	0.21				
Nitidula sp.	Ph	3	0.12			4	0.21	1	0.78	2	0.54
Urophorus humeralis (Fabricius, 1798)	Ph							1	0.78		
Oedemeridae		158	6.20	1	0.22	98	5.16				
Chrysanthia viridissima (Linnaeus, 1758)	F	132	5.18								
Oedemera barbara (Fabricius, 1792)	F	26	1.02	1	0.22	55	2.89				
Oedemera marmorata (Erichson, 1841)	F					43	2.26				
Phalacridae		2	0.08	1	0.22	14	0.74			1	0.27
Olibrus pygmaeus (Sturm, 1807)	M	2	0.08	1	0.22	10	0.53			1	0.27
Phalacrus coruscus (Panzer, 1797)	M					4	0.21				
Ptinidae		1	0.04	1	0.22	3	0.16			1	0.27
Dignomus irroratus (Kiesenwetter, 1851)	X	1	0.04			2	0.11				
Dignomus sp.	X					1	0.05				
Ptinus sp.	X			1	0.22					1	0.27
Scarabaeidae		166	6.51	11	2.41	114	6.00	7	5.47		
Amphimallon sp.	Ph					2	0.11				
Anisoplia baetica (Erichson, 1847)	F					4	0.21				
Anthoplia floricola (Fabricius 1787)	F					1	0.05				
Aphodius diecki (Harold, 1870)	C					1	0.05				
Aphodius sp.	C					1	0.05				
Blitopertha lineata (Fabricius, 1798)	F					1	0.05				
Euserica mamorensis (Baraud, 1965)	Ph	8	0.31	3	0.66	7	0.37	1	0.78		
Gymnopleurus flagellatus (Fabricius, 1787)	C	1	0.04								
Gymnopleurus sturmii (MacLeay, 1821)	C	1	0.04								
Hoplia africana (Escalera, 1914)	F					20	1.05				
Hoplia bilineata (Fabricius, 1801)	F					5	0.26				
Hoplia philanthus (Fuessly, 1775)	F	1	0.04			14	0.74				
Hymenoplia sp.	F			1	0.22	1	0.05	1	0.78		
Onthophagus maki (Illiger, 1803)	C	10	0.39								
Onthophagus sp.	C	9	0.35			3	0.16				
Oxythyrea funesta (Poda, 1761)	F	3	0.12			30	1.58	5	3.91		
Paratriodonta sp.	F	14	0.55			4	0.21				
Pleurophorus caesus (Creutzer, 1796)	C					7	0.37				
Protaetia opaca (Fabricius, 1787)	F	1	0.04			8	0.42				
Rhizotrogus sp.	Ph					1	0.05				
Scarabaeus cicatricosus (P.H.Lucas, 1846)	C	102	4.00	6	1.31	1	0.05				
Scarabaeus sacer (Linnaeus, 1758)	C	11	0.43								
Sphodroxia maroccana (Ley, 1923)	Ph	4	0.16	1	0.22						
Trichius zonatus (Germar, 1831)	F					2	0.11				
Tropinota squalida (Brullé, 1832)	F	1	0.04			1	0.05				

Annex. (Cont.)

		Stations									
		S1		S2		S3		S4		S5	
Taxon	**FG**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**	**ni**	**RA%**
Scolytidae		2	0.08	3	0.66	11	0.58			1	0.27
Hypoborus ficus (Erichson, 1836)	X					2	0.11			1	0.27
Platypus cylindrus (Fabricius, 1792)	X	1	0.04	3	0.66						
Scolytus sp.	X					1	0.05				
Scolytus sp.	X					1	0.05				
Xyleborus monographus (Fabricius, 1792)	X	1				7	0.37				
Scraptiidae		4	0.16			15	0.79	3	2.34	103	27.69
Anaspis sp.	F	4	0.16			8	0.42	2	1.56	1	0.27
Scraptia fuscula (Müller, 1821)	F					7	0.37	1	0.78	2	0.54
Trotomma sp.	F									100	26.88
Staphylinidae		3	0.12	1	0.22	89	4.68	2	1.56	4	1.08
Oxytelus sculptus (Gravenhorst, 1806)	Pr/N	2	0.08			2	0.11			3	0.81
Philonthus longicornis (Stephens, 1832)	Pr/N					20	1.05	1	0.78	1	0.27
Spedophilus marshami (Stephens, 1832)	Pr/N					1	0.05				
Stenus sp.	Pr/N					6	0.32				
Tachyporus hyponorum (Fabricius, 1775)	Pr/N			1	0.22	2	0.11				
Tachyporus nitidulus (Fabricius, 1781)	Pr/N					11	0.58				
Xantholinus linearis (Olivier, 1795)	Pr/N	1	0.04			47	2.47	1	0.78		
Tenebrionidae		1,708	67.03	245	53.61	549	28.89	1	0.78	150	40.32
Adelostoma sulcatum (Duponchel, 1829)	S	1	0.04	1	0.22						
Alphasida sp.	S					2	0.11				
Boromorphus tagenoides (Lucas, 1846)	S					1	0.05				
Cnemeplatia atropos (Costa, 1847)	S					2	0.11				
Cossyphus hoffmanseggi (Herbst, 1797)	S					9	0.47				
Erodius sp.	S	400	15.70	30	6.56	23	1.21				
Erodius sp.	S	45	1.77	6	1.31						
Gonocephalum granulatum granulatum (Fabricius, 1792)	S					1	0.05				
Heliotaurus ruficollis (Fabricius, 1781)	F	10	0.39			475	25.00				
Isomira melanophthalma (Lucas, 1846)	F	1	0.04			1	0.05	1	0.78		
Latheticus oryzae (Waterhouse, 1880)	S	1	0.05								
Opatrum sp.	S					2	0.11				
Pachychila sp.	S	503	19.74	8	1.75	20	1.05				
Pachychila sp.	S	337	13.23	55	12.04						
Pachychila sp.	S									150	40.32
Pimelia chrysomeloides subris (Koch, 1941)	S	100	3.92	13	2.84	3	0.16				
Pimelia sp.	S	184	7.22	125	27.35						
Sepidium bidentatum (Solier, 1843)	S	41	1.61			5	0.26				
Stenosis sp.	S	16	0.63	2	0.44	4	0.21				
Tenebrio sp.	S	1	0.04								
Zophosis minuta (Fabricius, 1775)	S	69	2.71	6	1.31						
Trogossitidae		1	0.04			1	0.05				
Temnoscheila caerulea (Olivier, 1790)	Pr	1	0.04			1	0.05				
Zopheridae				2	0.44	1	0.05				
Colobicus sp.	S			1	0.22						
Endophloeus markovichianus (Piller & Mitterpacher, 1783)	M			1	0.22	1	0.05				
N		2,548	100	457	100	1900	100	128	100	372	100