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Ground beetles of two cultivated orchards and one mixed forest near Mostaganem, Algeria (Coleoptera Carabidae)

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ABSTRACT The aim of this study is to investigate the environmental factors affecting the seasonal changes in carabid assemblages (Coleoptera Carabidae) inhabiting a vineyard field, a pomegranate orchard, and a mixed forest near Mostaganem (NW Algeria). The study area included agricultural and forested plots in the wilaya (province) of Mostaganem along the Mediterranean coast. Two plots were cultivated, a vineyard and a pomegranate orchard, while the third site was a mixed forest. Pitfall trapping was used to collect beetles between April 2019 and March 2020. Traps filled with propylene glycol were checked every 15 days during the year. A principal component analysis was used to reduce the components of the observed variation of species and specimens during the seasons. To achieve this aim, we used the PAST app. Each site showed peculiar temporal species succession, dominance, and species diversity (number of specimens and species); species in common to the three sites were few. The pomegranate orchard showed the highest diversity (29 species, 984 specimens). The vineyard harbored 16 species and 546 specimens, and the diversity peaked during autumn and early winter when grapes were harvested. The mixed forest was relatively poor in terms of species and specimens. Five species of *Graphipterus* were present here. The diversity of the faunistic assemblages varied notably among seasons of the same site and the sites; it was also quite distinct from that previously described for other cultures nearby. We could not fully assess the role of environmental factors in the carabid assemblages' dynamics and structure. Site management (culture, irrigation) likely affected the generalist carabids that dominated the cultures. Despite being relatively close and sharing similar environmental factors, sites harbored distinct species composition. We hypothesize that the hazardous dispersal of beetles also darkens the occurrence of patterns that model the composition of the assemblages.

KEY WORDS Community dynamics; seasonal and annual variation; pest biocontrol.

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INTRODUCTION

Insect communities are useful witnesses of how environmental factors influence living beings, affect the diversity of life histories and cycles, the trophic needs, and the ability to react to changes and perturbations. Carabid beetles make up one of the groups currently used to assess these changes as they show appropriate qualities: taxonomy is well-known, and their ecology has been documented for many countries, populations can be easily sampled, and they show responses to both small-scale requirements and landscape and continent level-phenomena (Hengeveld, 1987; Kotze & O'Hara, 2003; Koivula & Spence, 2006). They are widely considered 'bioindicators' (Kotze et al., 2011) as individual species or local assemblages. This consideration particularly applies to many European countries where many studies have been carried out (summarized in Kotze et al., 2011). Furthermore, ground beetles are also known to predate on pests, such as aphids, dipteran eggs and larvae, snails, caterpillars, eggs, and larvae of weevils, chrysomelids, and other harmful insects (Kromp, 1999; Monzó et al., 2011; Bouvet et al., 2019).

The knowledge about the distribution and the ecology of the Algerian ground-beetle fauna has notably increased during the last two decades thanks to the contributions of different authors who have investigated the occurrence of the species of environmental factors. It is worth mentioning the papers focused on saline areas (chotts) and freshwater lakes, which were studied by Boukli & Hassaine (2009), Boukli-Hacene et al. (2012), Chenchouni et al. (2015), Matallah et al. (2016), Amri et al. (2019), and Takieddine et al. (2023). Belhadid et al. (2014) studied the cedar forests of Chrèa and Djurdjura and that of Daas et al. (2016) on oak forests near Constantine. Carabid assemblages of agricultural landscapes of northeast Algeria have been studied by Ouchtati et al. (2012), focusing on cereal fields, and by Saouache et al. (2014), who compared the fauna of cereal fields and cherry orchards from two sites near Constantine (northeast Algeria). Recently, we also contributed to a study of assemblages inhabiting citric and olive cultures, an eucalyptus forest, and a fallow humid area near Mostaganem (Toutah et al., 2024). These sites showed a unique species' composition and dynamics with no shared pattern. Agricultural management likely gave rise to notable effects on soil moisture and texture, food availability, suitable environment for larval development, and thermal regulation of adults that must face extreme temperatures. Moreover, effects likely changed with seasons, conditioning the assemblage's final shape in the long run.

We aimed to get a broad picture of the ground beetle assemblages inhabiting nearby cultivated and non-cultivated sites, including a vineyard, a pomegranate orchard, and one mixed forest. Given the fine responses of carabids to environmental factors, we expected to find that each newly investigated site would also have a unique structure and dynamic pattern.

The sites were part of an agricultural landscape. For this reason, we also considered the role of this beetle fauna as a potential controller of insect pests, as Petremand et al. (2016) suggested.

MATERIAL AND METHODS

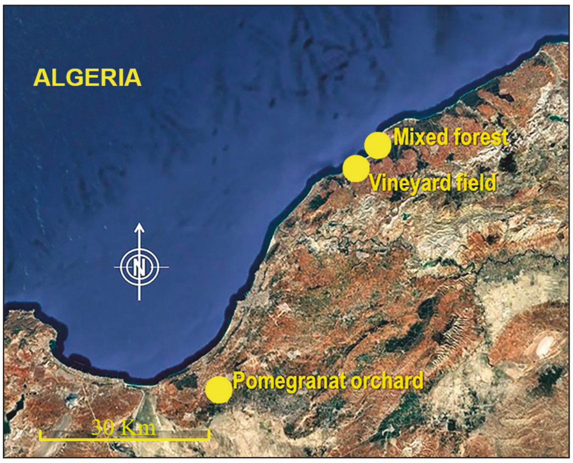
Study area

As described below, the area encompassed agricultural and forest-managed sites located in the wilaya (province) of Mostaganem along the Mediterranean coast (Fig. 1). There was a vineyard, a pomegranate orchard, and a mixed forest.

The vineyard was located on the Sub-Littoral Plain (36°7'35.95"N - 0°19'24.26"E) at an altitude of 177 m and covered 2.5 ha. Several grape varieties, such as Cinsault, Adari, Ferana, Dattier de Beyrouth, and Muscat, were cultivated on sandy soil. During the experiment, the vineyard was managed under a rainfed system, involving regular plowing and the application of phytosanitary treatments from winter to summer.

The pomegranate orchard was located on the Bordjias Plain (35°45'44.98"N / 0°4'18.65"E) at an altitude of 14 m and had a total area of 3.85 ha. The loamy soil was regularly plowed and weeded during the winter and spring seasons. Additionally, irrigation was implemented periodically throughout the experimental period. Phytosanitary treatments were applied during the experimental period, particularly in spring and summer.

The mixed forest was located on the Sub-littoral Plain (36°8'48.14 'N - 0°21'39.18 'E) at an altitude of 108 m. It covered an area of 3.8 ha, and the soil was sandy. The site included a forested patch with a dense shrubland cover and an arable patch (Fig. 2). The forest was dominated by *Juniperus phoenicea*; the arable patch was only plowed after the sampling time (March 2020). These contrasting conditions between the two patches have much-conditioned sampling results (see below in mixed forest results). No agrochemical products were applied during the sampling period.



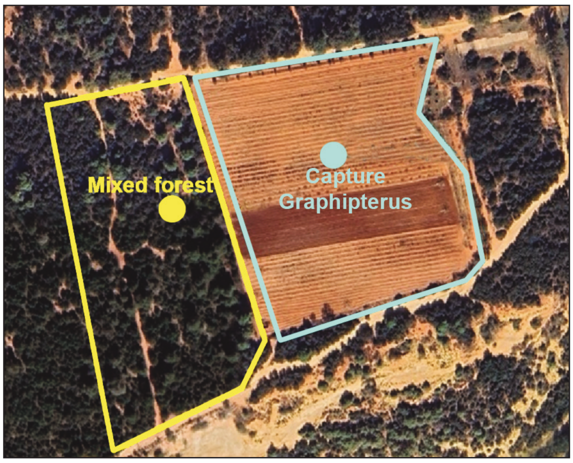


Figure 1. Map of northwest Algeria showing the location of the three studied sites.
Figure 2. Aerial view of the mixed forest site. The arable patch lies beside a forested patch with dense shrubland.

Climate

A semi-arid climate with mild winters characterizes the Mostaganem area. In 2019, total precipitation reached 415 mm, distributed unevenly throughout the year: a peak in November (107 mm), moderate rainfall from April to September, low amounts in June and July (>10 mm), and scarcity from May to August. The annual average temperature was 20.5 °C, with peaks in July and August (27 °C) and minimum values in January (15 °C) and February (16 °C).

During the 2020 campaign, precipitation decreased to 385 mm. It was moderate during September-November, January, and March-May, scarce in February and June-August, and high in December (112 mm). The annual average temperature was 21 °C, with a maximum of 27 °C in July and August and a recorded minimum in January (14 °C).

Sampling methods

Carabids were collected using the pitfall trap method. At each site, 60 traps were arranged in 15 spots; in each place, four traps formed a square of 5 m sides; the spots were separated by 15 m following a zigzag layout.

The traps consisted of two plastic containers of different sizes buried in the ground. The larger container was inserted into the soil with a diameter of 18 cm and a height of 20 cm. Inside this, a smaller container of 8 cm diameter and 11 cm height served as the collector for trapping arthropods and contained 150 ml of 50% aqueous solution of monopropylene glycol. Each trap was shielded from rain, plant debris, and other animals by a wooden plate supported by sticks.

The collected material was transferred to plastic containers and transported to the laboratory. The arthropods were rinsed with tap water, and the carabid specimens were separated and preserved in 70% ethanol until identification.

Sampling started in April 2019 and ended in March 2020. Traps were emptied every 15 days. Spring captures were those between 06/04/2019 and 18/06/2019; summer captures between 19/06/2019 and 19/09/2019; autumn captures between 20/09/2019 and 23/12/2019; and winter data between 24/12/2019 and 19/03/2020.

Species were identified by J. Serrano and D. Toutah using current literature on taxonomy and species distribution, as indicated in Toutah et al. (2024).

Data analysis

We analyzed data matrices with the PAST application (Hammer et al., 2025) version 5.01 (February 2025). The captures of each 15-day interval were scored in an Excel file, and thereafter, we added columns summarizing captures of each season and a total-year column (the General Matrix data). We first analyzed the captures of all sampling events using a Principal Component Analysis (PCA). In a second analysis, we considered the trapping data grouped by seasons (the Season Matrix) and got the alfa- and beta-diversity seasonal indices and a Bray-Curtis similarity dendrogram between seasons. The dendrogram was estimated using pairwise comparisons under the Whitaker option of PAST.

Due to the large size of the General Matrix, we stored the files corresponding to the three sites in the Supplementary Tables (S1, S2, and S3).

RESULTS

The vineyard

At this site, a total of 16 species and 546 specimens were collected (General Matrix, Table S1).

The four species that comprised the bulk of captures dominated the site (Table 1) through the seasons. As expected from a generalist autumn breeder, *Calathus mollis* was notably active in November and December. The pattern shown by *Orthomus abacoides* is slightly different, as a fair number of captures were found throughout the whole year. *Poecilus lucasii* was collected only in winter and spring. We also found this pattern in *Harpalus distinguendus*.

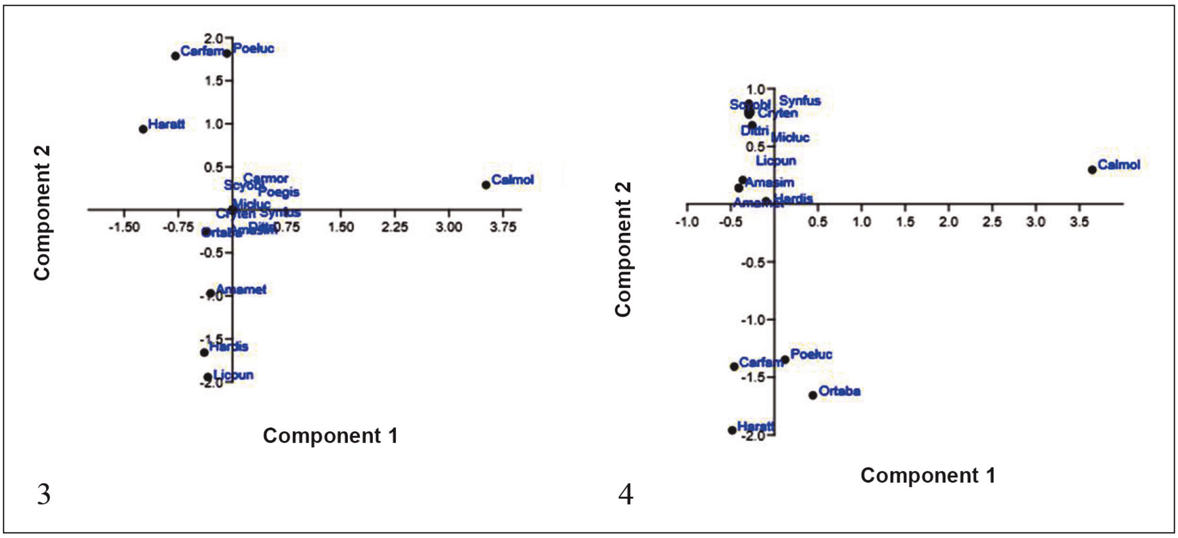
Carabid assemblages notably changed through seasons; the winter assemblage was made up of eight species with a mixture of autumn, autumn-winter, and winter breeders that yielded the highest number of trapped beetles, 230 specimens (Table 1). A few autumn breeders, like *Calathus mollis,* can survive until the following spring, whereas typical spring breeders (*Poecilus lucasii, Harpalus distinguendus*) hardly survive until summer. In this last season, the species diversity was unexpectedly high

Species	**Acronym**	**Spring**	**Summer**	**Autumn**	**Winter**
Carabus (Eurycarabus) famini numidus Laporte, 1834	Carfam			1	
Carabus (Macrothorax) morbillosus morbillosus Fabricius, 1792	Carmor	1	1		
Orthomus (Orthomus) abacoides (Lucas, 1846)	Ortaba	13	2	49	23
Poecilus (Ancholeus) gisellae gisellae Csiki, 1930	Poegis	2			
Poecilus (Poecilus) lucasii (Reiche, 1861)	Poeluc	44	1		10
Amara (Acorius) metallescens (Zimmermann, 1831)	Amamet				1
Amara (Paracelia) simplex Dejean, 1828	Amasim				1
Calathus (Neocalathus) mollis atticus Gautier, 1867	Calmol	12	1	159	169
Scybalicus oblongiusculus (Dejean, 1829)	Scyobl		1		
Ditomus tricuspidatus (Fabricius, 1792)	Dittri		2		
Cryptophonus tenebrosus (Dejean, 1829)	Cryten		2		
Harpalus attenuatus Stephens, 1828	Haratt	1	1	6	1
Harpalus distinguendus (Duftschmid, 182)	Hardis	6			21
Licinus (Licinus) punctatulus (Fabricius, 1792)	Licpun	1			4
Microlestes luctuosus chobauti Jeannel, 1942	Micluc		6		
Syntomus fuscomaculatus (Motschulsky, 1844)	Synfus	3	1		
		83	**18**	**215**	**230**

Table 1. Trapping data of ground beetles grouped by seasons in a vineyard field of Mostaganem (2019–2020).

	Spring	Summer	Autumn	Winter
Taxa_S	9	10	4	8
Specimens	83	18	215	230
Dominance_D	0.3259	0.1176	0.5978	0.5586
Simpson_1-D	0.6741	0.8824	0.4022	0.4414
Shannon_H	1.514	2.312	0.692	0.9682
Evenness_e^H/S	0.505	1.01	0.4994	0.3291
Margalef	1.81	3.114	0.5586	1.287
Equitability_J	0.6671	0.8955	0.4941	0.4583
Fisher_alpha	2.566	9.264	0.6976	1.61
Berger-Parker	0.5301	0.3333	0.7395	0.7348
iChao-1	14.05	15.67	4	10.99
ACE	12.91	21.88	5.111	13.72
Squares	12.02	17.36	4.6	13.05

Table 2. Seasonal changes of α-diversity indices of carabid assemblages in a vineyard field near Mostaganem (2019-2020).



Figures 3, 4. Vineyard field. Fig. 3: Scatter plot of a Principal Component Analysis (PCA) based on the data of the General Matrix. Fig. 4: PCA based on the data of the Seasonal Matrix. Abbreviations as in Table 1.

(10 species, Table 1), but beetle captures were scarce, and only taxa of the tribe Lebiini (*Microlestes* and *Syntomus*) were more abundant. In contrast, the Shannon index was relatively low in autumn (0.692) as only four species were active but with abundant specimens.

When the data of the General Matrix (Table S1) were subjected to a PCA (Fig. 3), we found that the

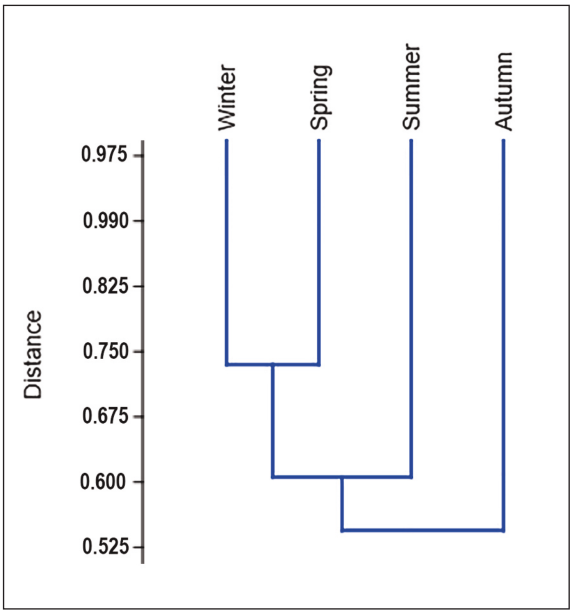


Figure 5. Bray-Curtis dendrogram of faunistic similarity between seasons in a vineyard of Mostaganem.

first five axes were needed to explain at least 98.25% of the total variance. The first axis, likely corresponding to *Calathus mollis*, explained 83.234% of the variance.

Table 1 shows the capture data grouped by seasons of the Season Matrix. We subjected this matrix to a new PCA and found that the first three axes now explained 99.94% of the total variance (Fig. 4); the first axis (*Calathus mollis*) explained 88,537% of the variance.

This analysis also found the α-diversity between seasons (Table 2). The highest Shannon's value was found in summer (2.312) but was also high in spring. Index values became low or very low during Autumn.

The ß-diversity values (not shown) were used to estimate the faunistic similarity between seasons by calculating a Bray-Curtis similarity dendrogram (Fig. 5). Autumn's assemblage was the most distinct, whereas spring and winter's were the most related.

The chorological profile of the fauna inhabiting the vineyard field consisted of species with an endemic pattern (endemisms and North-African elements; 37.50%), followed by species with a Mediterranean distribution pattern (31.25%), and species with a wide distribution (Cosmopolitan, Palearctic, West Palearctic, Centro-Asiatic and others (31.25%)

The pomegranate orchard

The site totaled 984 specimens and 30 species (General Matrix, Table S2). Three species were represented by more than 100 specimens , of which *Pseudoophonus griseus* (499 specimens , mean body size 10 mm) and *Orthomus abacoides* (162 specimens , mean body size 11.3 mm) made up the bulk of specimens of the assemblage, followed by *Syntomus fuscomaculatus* (138 specimens , mean body size 3.9 mm). The most abundant species showed a higher activity pattern in spring (Table 3), activity that was continued with lower intensity during summer (*Orthomus abacoides, Pseudoophonus* spp) and even throughout the other seasons. Winter-spring breeders with activity almost restricted to spring were *Laemostenus algerinus* and *Harpalus distinguendus*. In contrast, small species of the tribe Lebiini were particularly active in summer.

The Principal Component Analysis (Fig. 6) of the General Matrix (Table S2) showed that the total variance was mainly distributed within the first six axes, indicating a fair heterogeneity of species abundance throughout seasons. The matrix's analysis with only seasonal data (Table 3) resulted in a scatter plot (Fig. 7) where the abundant taxa are differentiated from the rest of the species. The first two axes explained 99.1% of the total variance.

The α-diversity index showed that the assemblages of winter and spring had the highest Shannon's indices (Table 4). Young adults that hatched during the spring can survive until the onset of autumn (*Orthomus abacoides, Pseudoophonus* spp.), but in most cases, they disappear with the onset of the summer. The activity pattern of the summer was unusually high due to the survival of the two most abundant species and the hatching of *Microlestes luctuosus* and *Syntomus fuscomaculatus* adults, which were relatively abundant. Trapping results likely underestimated the density of these Lebiini taxa, as beetles can escape from traps by flying. The species number and abundance of specimens notably declined in autumn and winter (Table 3).

The autumn assemblage was relatively poor and was characterized by medium-sized beetles able to survive the summer climate. The winter fauna was almost made up of typical winter breeders (*Laemostenus terricola, Harpalus distinguendus*) and specimens of *Orthomus abacoides* (Table 3). The

Species	Acronym	Spring	Summer	Autumn	Winter
Calosoma maderae maderae (Fabricius, 1775)	Calmad	1			
Bembidion (Neja) ambiguum Dejean, 1831	Bemamb	1			
Percus (Percus) lineatus (Solier, 1835)	Perlin	1			
Orthomus (Orthomus) abacoides (Lucas, 1846)	Orabac	131	4	11	16
Orthomus (Orthomus) lacouri pupieri Jeanne, 1988	Orlac	3			
Amara (Amara) aenea (DeGeer, 1774)	Amaen	1			
Amara (Amara) similata (Gyllenhal, 1810)	Amsimi				2
Amara (Celia) fervida fervida Coquerel, 1859	Amferv	1			
Amara (Amara) eurynota (Panzer, 1796)	Ameury				1
Calathus (Bedelinus) circumseptus Germar, 1827	Calcirc	1			
Calathus (Neocalathus) mollis atticus Gautier, 1867	Calmoll			2	
Laemostenus (Laemostenus) complanatus (Dejean, 1828)	Laecom	3			
Laemostenus (Pristonychus) algerinus algerinus Gory, 1833	Laealg	10	1	2	
Laemostenus (Pristonychus) terricola terricola (Herbst, 1784)	Laeter			10	7
Cryptophonus tenebrosus (Dejean, 1829)	Cryten	1		1	
Harpalus (Harpalus) attenuatus Stephens, 1828	Haratt	1			
Harpalus (Harpalus) distinguendus distinguendus (Duftschmid, 1812)	Hardis	27			5
Harpalus (Harpalus) angustitarsis Reitter, 1887	Harang		1		
Ophonus (Ophonus) quadricollis (Dejean, 1831)	Ophqua			1	
Parophonus (Parophonus) hispanus (Rambur, 1838)	Parhisp	1			
Pseudoophonus griseus (Panzer, 1796)	Psgris	223	194	82	
Pseudoophonus rufipes (DeGeer, 1774)	Psrufi	17	4	5	
Licinus (Licinus) punctatulus punctatulus (Fabricius, 1792)	Licpun		1	1	1
Platytarus faminii faminii (Dejean, 1826)	Plafami	1			
Microlestes fissuralis (Reitter, 1901)	Micfiss	1			
Microlestes luctuosus chobauti Jeannel, 1942	Micluct	1	59		4
Microlestes negrita negrita (Wollaston, 1854)	Micnegr	2			
Syntomus foveatus (Geoffroy, 1785)	Synfov	1			
Syntomus fuscomaculatus (Motschulsky, 1844)	Synfus	36	86	16	
Syntomus obscuroguttatus (Duftschmid, 1812)	Synobs		2		
		465	**352**	**131**	**36**

Table 3. Trapping data of ground beetles grouped by seasons, in a pomegranate orchard near Mostaganem (2019-2020).

	Spring	Summer	Autumn	Winter
Taxa_S	22	9	10	7
specimens	465	352	131	36
Dominance_D	0.3192	0.3901	0.4173	0.2508
Simpson_1-D	0.6808	0.6099	0.5827	0.7492
Shannon_H	1.559	1.165	1.353	1.64
Evenness_e^H/S	0.2161	0.356	0.3868	0.7366
Margalef	3.419	1.364	1.846	1.674
Equitability_J	0.4971	0.5248	0.5726	0.8
Chao-1	60.92	10.5	10.99	7.486
iChao-1	112.3	13.49	12.23	8.944
ACE	85.19	11.97	14.58	8.407
Squares	76.27	12.53	13.8	8.098

Table 4. Seasonal changes of α-diversity indices of carabid assemblages in a pomegranate orchard near Mostaganem (2019-2020).

number of beetles of this last species steadily increased as spring approached (Table S2).

Comparisons between seasons showed (Fig. 8) a low Bray-Curtis similarity value between winter and spring, and a higher value between summer and autumn assemblages.

The chronological profile of the fauna inhabiting the pomegranate orchard consisted of species with an extensive distribution area (Cosmopolitan, Palearctic, West Palearctic, Centro-Asiatic, Turanic-Mediterranean, and others: 53.33%), followed by the Mediterranean elements (23.33%) and Maghrebian elements (endemisms, North-African, 20%).

The mixed forest

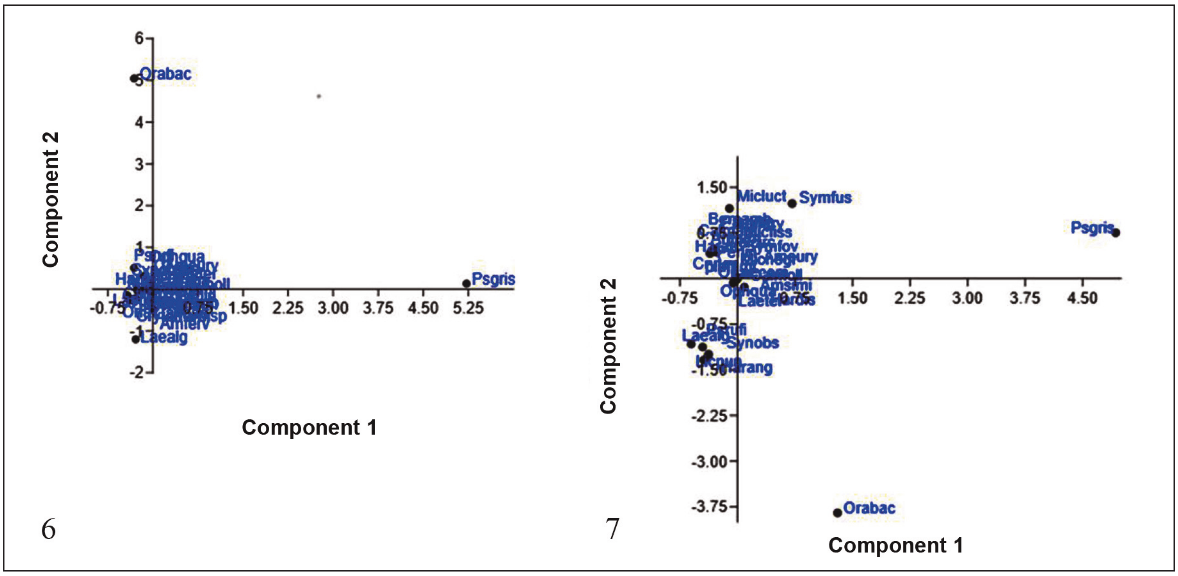
The number of beetles trapped at this site was relatively low: 125 specimens during the year (General Matrix, Table S3). The genus *Graphipterus* Latreille, 1802 was solely collected in the arable patch during the spring but not in the forested patch. In contrast, the other species were only trapped in pitfall traps placed within the forest and shrubland: only three beetles during summer and 8 and 13 during autumn and winter, respectively.

We collected 92 *Graphipterus* specimens ; in the forested patch, the dominant species belonged to the tribe Sphodrini (*Platyderus gregarius, Calathus opacus*). The five species of *Graphipterus* are of medium-large size, ranging between 12 and 19 mm (Renan et al., 2018), meaning they represent the bulk of carabid biomass in the sampled area. Beetle activity suggests that all *Graphipterus* taxa and *Platyderus gregarius* are spring-breeders; only *Calathus opacus* is an autumn-breeder.

When the General Matrix with all data (Table S3) was run in PAST, the first five axes were needed to explain 99% of the total variance, which suggests a diversified structure assemblage. When the Season Matrix (Table 5) was run, the first two axes explained 99% of the variance due to the variation of *Graphipterus luctuosus* and *Platyderus gregarius.*

The analysis of the Season Matrix showed the α-diversity indices indicated in Table 6, which were moderate or low when considering the highest Shannon's indices: 1.44 in spring and 1.748 in winter.

The summer's assemblage was the most different due to the low number of species and specimens captured, followed by the spring's assemblage with the highest number of specimens and species.



Figures 6, 7. Pomegranate orchard. Fig. 6: Scatter plot of a Principal Component Analysis (PCA) based on the data of the General Matrix. Fig. 7: PCA based on the data of the Seasonal Matrix. Abbreviations as in Table 3.

The site's chorological profile was similar for the arable patch and the forested zone, as both were dominated by endemic elements restricted to Algeria (pure endemics) or the Maghrebian area (North-African elements). Only *Laemostenus terricola* and *Syntomus fuscomaculatus* are species with a wide distribution area.

DISCUSSION

Seasonal dynamics within the sites

The first general result was the dominance of a few species in all the sites where enough beetles were trapped. These findings about the dominant taxa resemble those described for the other four sites also located in the surroundings of Mostaganem (Toutah et al., 2024). The dominance of spring breeders was usually limited to this season (*Poecilus lucasii, Harpalus distinguendus*). In contrast, dominant taxa hatching in late spring also showed high activity during summer, autumn (*Pseudoophonus* spp) and even winter (*Orthomus abacoides*). The summer period is quite good for small Lebiini taxa of the genera *Microlestes* and *Syntomus*, as found by Toutah et al. (2024) in other sites around Mostaganem.

The chorological profile of the sites reflected the effect of management and vegetation coverage. The vineyard was subjected to plowing and other human activities to harvest the grapes. However, the soil lacks vegetation throughout the year, limiting the settlement of many carabid species that are hygrophilous generalists. Therefore, it was expected that Maghrebian and Mediterranean elements were in a higher proportion (68.28%) than the generalist taxa (31.25%). These percentages change in the pomegranate orchard with better shade and soil moisture. Here, the generalist taxa were 53.33% of all species. In the arable part of the mixed forest, only *Graphipterus* species were found (Maghrebian distribution pattern). In contrast, in the forested area Maghrebian elements dominated, although one western Palearctic and one Euro-Mediterranean species were also caught. These results indicate that the forested patch has been subjected to weak management in recent years, thus allowing the occurrence of autochthonous taxa. The most striking result, both in the arable and the forest patches, was the sharp decline in the number of beetles captured during summer and autumn. As no agrochemical products were applied during the experiment, a detailed study of soil parameters and vegetation cover is needed to gain insights into these unexpected results.

In summary, of the seven studied sites (Toutah et al., 2024; this paper) the highest percentages of

		Spring	Summer	Autumn	Winter
Carabus (Eurycarabus) famini numidus Laporte, 1834	Carfam	2	0		1
Poecilus (Poecilus) lucasii (Reiche, 1861)	Poeluc	0	0		1
Amara (Paracelia) simplex simplex Dejean, 1828	Amasim	1	0		0
Platyderus (Platyderus) gregarius Reiche, 1862	Plagre	4	0		7
Calathus (Calathus) opacus Lucas, 1846	Calopa	0	0	7	1
Calathus (Neocalathus) melanocephalus antoinei Puel,1939	Calmel	2	0		0
Laemostenus (Pristonychus) terricola terricola (Herbst, 1784)	Laeter	0	0		1
Graphipterus exclamationis exclamationis (Fabricius, 1792)	Graexc	2	0		0
Graphipterus luctuosus Dejean, 1825	Graluc	47	0		0
Graphipterus peletieri Laporte de Castelnau, 1840	Grapel	19	0		0
Graphipterus rotundatus Klug, 1832	Grarot	23	0		0
Graphipterus valdanii Guérin-Méneville, 1859	Graval	1	0		0
Cymindis (Cymindis) setifeensis leucophthalma Lucas, 1842	Cymset	0	1		0
Microlestes luctuosus chobauti Jeannel,1942	Micluc				1
Syntomus fuscomaculatus (Motschulsky, 1844)	Synfus		2	1	1
		103	**3**	**8**	**13**

Table 5. Trapping data of ground beetles grouped by seasons collected in a mixed forest of the region of Mostaganem during 2019-2020.

	Spring	Summer	Autumn	Winter
Taxa_S	9	2	2	7
specimens	101	3	8	13
Dominance_D	0.2998	0.3333	0.75	0.2692
Simpson_1-D	0.7002	0.6667	0.25	0.7308
Shannon_H	1.499	0.8032	0.4393	1.748
Evenness_e^H/S	0.4975	1.116	0.7758	0.8204
Margalef	1.733	0.9102	0.4809	2.339
Fisher_alpha	2.389	2.622	0.8559	6.182
Berger-Parker	0.4653	0.6667	0.875	0.5385
Chao-1	9.248	2.333	2	20.85
ACE	10.2	3	3.102	40.86
Squares	10.23	2.714	2.806	22.59

Table 6. Seasonal changes of α-diversity indices of carabid assemblages in a mixed forest of Mostaganem (2019-2020).

species with a wide distribution area were those with humid soils due to irrigation of closeness to rivers: the pomegranate orchard, the fallow humid zone, and the citric orchard. Here, the generalist hygrophilous taxa find suitable environments to occur.

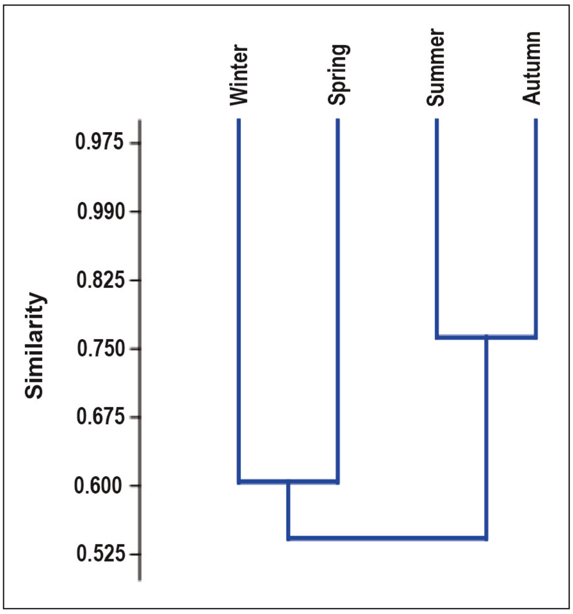
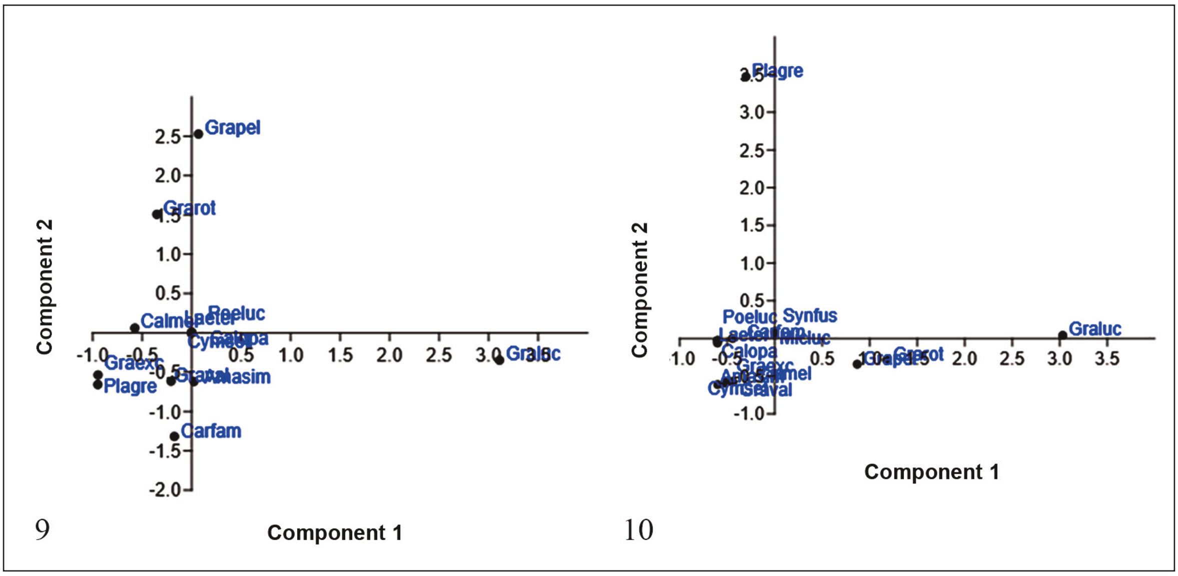


Figure 8. Bray-Curtis dendrogram of faunistic similarity between seasons in a pomegranate orchard of Mostaganem.

The Mediterranean elements were present in percentages between 30% and 35%. The endemic taxa were mostly concentrated in the forested areas of the mixed forest (86.67%) and the eucalyptus forest (61.91%; Toutah et al., 2024). As noted above, the forested sites have been subjected to scarce management, which seems to favor the settlement of autochthonous taxa.

Saouache et al. (2014) studied a cherry orchard near Constantine for 3 years and found 23 species but fewer specimens (229). Although the species composition of the Constantine assemblage differed from that of the orchards of Mostaganem, the assemblages shared the occurrence of *Pseudoophonus* spp, *Harpalus distinguendus,* and *Licinus punctatulus,* generalist predators or omnivorous taxa.

The carabid assemblage of the mixed forest is hardly comparable to that of the El-Kala and Souk-Ahras *Quercus* forests (NE Algeria; Daas et al., 2016), as these were characterized by species of temperate Mediterranean forests (genera *Carabus* Linnaeus, 1758*, Nebria* Latreille, 1802, and *Harpalus* Latreille, 1802; none *Graphipterus* taxa). The Chrèa and Djurdjura cedar forests (Belhadid et al., 2014) harbored typical forest taxa of the genera *Calathus* and *Nebria*. However, generalist species proper of open habitats were also found



Figures 9, 10. Mixed forest. Fig. 9: Scatter plot of a Principal Component Analysis (PCA) based on the data of the General Matrix. Fig. 10: PCA based on the data of the Seasonal Matrix. Abbreviations as in Table 5.

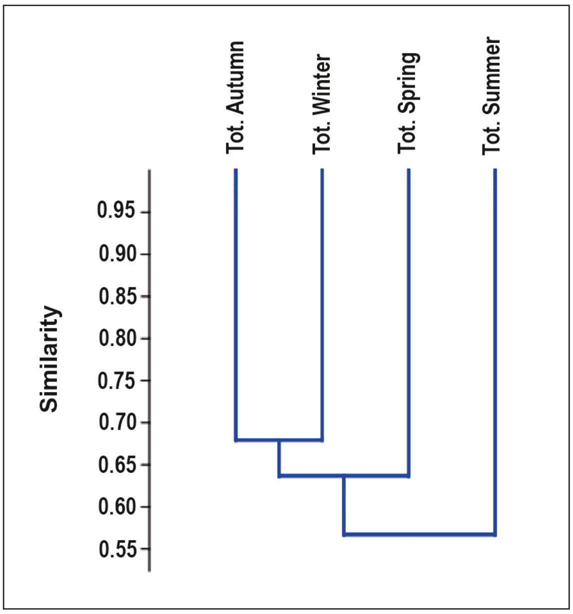


Figure 11. Bray-Curtis dendrogram of faunistic similarity between seasons in a mixed forest of Mostaganem.

(*Harpalus attenuatus* and *Zabrus jurjurae* Peyerimhoff, 1908). Thus, the carabid assemblage of the mixed forest deserves a more in-depth study to gain insights into the factors influencing the species composition.

Trophic preferences and pest biocontrol

Large predators (*Carabus* spp.) were scarce in the vineyard and the pomegranate orchard. Its role is likely assumed by medium-sized predators as *Poecilus lucasii* (body size 12–14 mm), the most abundant predator within the vineyard (55 specimens) during the winter-spring seasons.

Pseudoophonus rufipes (body size 11–16 mm) is known to be a pest predator (Monzó et al., 2011). However, the number of specimens in the pomegranate orchard was not high throughout the seasons (Table 3). However, the related *P. griseus* (body size 9–11 mm) may replace its role, given the high number of specimens trapped between spring and autumn (Table 3). In the pomegranate orchard, these two species are accompanied by *Orthomus abacoides* (Table 3) and the *Laemostenus* spp. (Table 3), making up a set of predators with possible biocontrol value. Abd-Ella (2015) found that beetles were more abundant when the pomegranate trees are flowering and may be attacked by the aphids. Likewise, according to Petremand et al. (2016), the ground beetle fauna may attack pests whose life cycle is partially developed in the soil or feed on suitable larval stages that fall from the plants. Therefore, the role of ground beetles depends on the diversity and abundance of predators; according to Putchkov (2015), beetles of the genera *Microlestes* and *Syntomus* are zoophagous and must also be considered effective predators when they are present in large numbers despite their small size, as found in the pomegranate orchard (Table 3).

CONCLUSIONS

Carabid assemblages in three Mostaganem (Algeria) sites showed notable differences in species composition and dynamics through seasons due to the species diversity of phenology and life cycle. Diversity was affected by a few dominant species in all sites; it was high in a pomegranate orchard and decreased significantly in a vineyard and one mixed forest divided into one arable and one forested patch. Diversity was higher in managed (cultivated) sites due to generalist species with large distribution areas, whereas Maghrebian elements were more abundant in the mixed forest with low management. The assemblages of ground beetles inhabiting the cultivated sites may be beneficial in controlling insect pests, but further studies of trophic preferences are needed to assess the postulated benefit.

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Table S1. Part 1. Captures of ground beetles in a vineyard of Mostaganem during Spring-Summer, 2019-2020.

	SP1	SP2	SP3	SP4	SP5	SP6	Tot Spring	SU1	SU2	SU3	SU4	SU5	SU6	Tot Summ
Sampling date	11-4	20-4	4-5	18-5	1-6	20-6		6-7	20-7	7-8	21-8	5-9	19-9	
Carabus famini numidus Laporte, 1834														
Carabus morbillosus morbillosus Fabricius, 1792						1	**1**	1						**1**
Orthomus abacoides (Lucas, 1846)	6	2	1			4	**13**						2	**2**
Poecilus gisellae gisellae Csiki, 1930			2				**2**							
Poecilus lucasii (Reiche, 1861)	34	6	3			1	**44**	1						**1**
Amara metallescens (Zimmermann, 1831)														
Amara simplex Dejean, 1828														
Calathus mollis atticus Gautier, 1867	12						**12**		1					**1**
Scybalicus oblongius-culus (Dejean, 1829)								1						**1**
Ditomus tricuspidatus (Fabricius, 1792)									1	1				**2**
Cryptophonus tenebrosus (Dejean, 1829)										2				**2**
Harpalus attenuatus Stephens, 1828					1		**1**					1		**1**
Harpalus distinguendus (Duftschmid, 182)	4	2					**6**							
Licinus punctatulus (Fabricius, 1792)	1						**1**							
Microlestes luctuosus chobauti Jeannel, 1942								1		3		1	1	**6**
Syntomus fuscomaculatus (Motschulsky, 1844)				3			**3**	1						**1**
	57	10	6	3	1	6	**83**	5	2	6	0	2	3	**18**

Table S1 (continued). Captures of ground beetles in a vineyard of Mostaganem during Autumn-Winter, 2019-2020.

	AU 1	AU 2	AU 3	AU 4	AU 5	AU 6	Tot Aut	WI1	WI2	WI3	WI4	WI5	WI6	Tot. Win	Tot. Year
Sampling date	4 Oct	19-Oct	04-Nov	19-Nov	04-Dic	23-Dic		07-Jan	23-Jan	05-Feb	19-Feb	04-Mar	19-Mar		
Carabus famini numidus Laporte, 1834					1		1								1
Carabus morbillosus morbillosus Fabricius, 1792															2
Orthomus abacoides (Lucas, 1846)			5	9	23	12	49	2	16	4	1			23	87
Poecilus gisellae gisellae Csiki, 1930															2
Poecilus lucasii (Reiche, 1861)										2	4	1	3	10	55
Amara metallescens (Zimmermann, 1831)									1					1	1
Amara simplex Dejean, 1828											1			1	1
Calathus mollis atticus Gautier, 1867			6	21	96	36	159	31	71	37	7	11	12	169	341
Scybalicus oblongiusculus (Dejean, 1829)															1
Ditomus tricuspidatus (Fabricius, 1792)															2
Cryptophonus tenebrosus (Dejean, 1829)															2
Harpalus attenuatus Stephens, 1828	1		1	1	2	1	6		1					1	9
Harpalus distinguendus (Duftschmid, 1812)									1	2	2	9	7	21	27
Licinus punctatulus (Fabricius, 1792)								1	3					4	5
Microlestes luctuosus chobauti Jeannel, 1942															6
Syntomus fuscomaculatus (Motschulsky, 1844)															4
	1	0	12	31	122	49	215	34	93	45	15	21	22	230	546

Table S2. Part 1. Captures of ground beetles in a pomegranate orchard of Mostaganem during Spring-Summer, 2019-2020.

	SP1	SP2	SP3	SP4	SP5	SP6	Tot. Spring	SU1	SU2	SU3	SU4	SU5	SU6	Tot. Summer
Sampling date	6-4	20-4	4-5	18-5	1-6	18-6		6-7	20-7	7-8	21-8	5-9	19-9	
Calosoma maderae maderae (Fabricius, 1775)	1						1							
Bembidion ambiguum Dejean, 1831	1						1							
Percus lineatus (Solier, 1835)			1				1							
Orthomus abacoides (Lucas, 1846)	48	36	16	11	15	5	131			2		1	1	4
Orthomus lacouri pupieri Jeanne, 1988				1	2		3							
Amara aenea (DeGeer, 1774)	1						1							
Amara eurynota (Panzer, 1796)														
Amara similata (Gyllenhal, 1810)														
Amara fervida fervida Coquerel, 1859	1						1							
Calathus circumseptus Germar, 1827					1		1							
Calathus mollis atticus Gautier, 1867														
Laemostenus complanatus (Dejean, 1828)					2	1	3							
Laemostenus algerinus algerinus Gory, 1833	1	1	2	1	5		10			1				1
Laemostenus terricola terricola (Herbst, 1784)														
Cryptophonus tenebrosus (Dejean, 1829)					1		1							
Harpalus attenuatus Stephens, 1828					1		1							
Harpalus distinguendus distinguendus (Duftschmid,1812)	11	8	3		1	4	27							
Harpalus angustitarsis Reitter, 1887								1						1
Ophonus quadricollis (Dejean, 1831)														
Parophonus hispanus (Rambur,1838)	1						1							
Pseudoophonus griseus (Panzer, 1796)	7	5	1	30	129	51	223	70	7	10	51	33	23	194
Pseudoophonus rufipes (DeGeer, 1774)					13	4	17		1			1	2	4
Licinus punctatulus (Fabricius, 1792)													1	1

Platytarus faminii faminii (Dejean, 1826)				1			1							
Microlestes fissuralis (Reitter, 1901)					1		1							
Microlestes luctuosus chobauti Jeannel, 1942			1				1	11	11	21	4	4	8	59
Microlestes negrita negrita (Wollaston, 1854)				1		1	2							
Syntomus foveatus (Geoffroy, 1785)					1		1							
Syntomus fuscomaculatus (Motschulsky, 1844)	1			19	13	3	36	35	9	12	13	5	12	86
Syntomus obscuroguttatus (Duftschmid, 1812)								1		1				2
	73	50	24	64	185	69	465	118	28	47	68	44	47	352

Table S2 (continued). Captures of ground beetles in a pomegranate orchard of Mostaganem during Autumn-Winter, 2019-2020.

	AU1	AU2	AU3	AU4	AU5	AU6	Tot. Aut	WI1	WI2	WI3	WI4	WI5	WI6	Tot. Win	Year
Sampling date	4-10	19-10	4-11	19-11	4-12	23-12		7-1	22-1	5-2	19-2	4-3	19-3		
Calosoma maderae maderae (Fabricius, 1775)															1
Bembidion ambiguum Dejean, 1831															1
Percus lineatus (Solier, 1835)															1
Orthomus abacoides (Lucas, 1846)	2	2	2		3	2	11		1	3	1	3	8	16	162
Orthomus lacouri pupieri Jeanne, 1988															3
Amara aenea (DeGeer, 1774)															1
Amara eurynota (Panzer, 1796)												1		1	1
Amara similata (Gyllenhal, 1810)										1		1		2	2
Amara fervida fervida Coquerel, 1859															1
Calathus circumseptus Germar, 1827															1
Calathus mollis atticus Gautier, 1867					1	1	2								2
Laemostenus complanatus (Dejean, 1828)															3
Laemostenus algerinus algerinus Gory, 1833			1	1			2								13
Laemostenus terricola terricola (Herbst, 1784)			1	6	2	1	10			3	1		3	7	17
Cryptophonus tenebrosus (Dejean, 1829)						1	1								2
Harpalus attenuatus Stephens, 1828															1
Harpalus distinguendus distinguendus (Duftschmid,1812)											2		3	5	32
Harpalus angustitarsis Reitter, 1887															1
Ophonus quadricollis (Dejean, 1831)	1						1								1
Parophonus hispanus (Rambur,1838)															1
Pseudoophonus griseus (Panzer, 1796)	61	4	11	5		1	82								499
Pseudoophonus rufipes (DeGeer, 1774)	1	3			1		5								26
Licinus punctatulus (Fabricius, 1792)			1				1	1						1	3

Platytarus faminii faminii (Dejean, 1826)															1
Microlestes fissuralis (Reitter, 1901)															1
Microlestes luctuosus chobauti Jeannel, 1942											3	1		4	64
Microlestes negrita negrita (Wollaston, 1854)															2
Syntomus foveatus (Geoffroy, 1785)															1
Syntomus fuscomaculatus (Motschulsky, 1844)	9		3	2	2		16								138
Syntomus obscuroguttatus (Duftschmid, 1812)															2
	74	9	19	14	9	6	**131**	1	1	7	7	6	14	**36**	**984**

Table S3. Part 1. Captures of ground beetles in a mixed forest of Mostaganem during Spring-Summer 2019-2020. Columns without any captured beetles (e.g., Aut 3, Aut 5) have been deleted.

	SP1	SP2	SP3	SP4	SP5	SP6	Tot. Spring	SU1	SU2	SU3	SU4	SU5	SU6	Tot. Sum
Date of sampling	6-4	20-4	4-5	18-5	1-6	18-6		6-7	20-7	7-8	21-8	5-9	19-9	
Carabus famini numidus Laporte, 1834		1	1				**2**							
Poecilus lucasii (Reiche, 1861)							**0**							
Amara (simplex simplex Dejean, 1828			1				**1**							
Platyderus gregarius Reiche, 1862		1	2	1			**4**							
Calathus opacus Lucas, 1846							**0**							
Calathus melanocephalus antoinei Puel, 1939				2			**2**							
Laemostenus terricola terricola (Herbst, 1784)							**0**							
Graphipterus exclamationis exclamationis (Fabricius, 1792)		1		1			**2**							
Graphipterus luctuosus Dejean, 1825	10	11	1	19	1	5	**47**							
Graphipterus peletieri Laporte de Castelnau, 1840	3	5	4	6		1	**19**							
Graphipterus rotundatus Klug, 1832	5	3	6	4		5	**23**							
Graphipterus valdanii Guérin-Méneville, 1859		1					**1**							
Cymindis setifeensis leucophthalma Lucas, 1842							**0**		1					1
Microlestes luctuosus chobauti Jeannel, 1942														
Syntomus fuscomaculatus (Motschulsky, 1844)									1		1			**2**
	18	23	15	33	1	11	**101**	0	1	0	0	0	0	**3**

Table S3 (continued). Captures of ground beetles in a mixed forest of Mostaganem during Autumn-Winter 2019-2020. Columns without any captured beetles have been deleted.

	AU2	AU4	**Tot. Aut**	WI2	WI3	WI5	WI6	**Tot. Win**	**Year**
Date of sampling	19-10	19-11		22-1	5-2	4-3	19-3		
Carabus famini numidus Laporte, 1834							1	1	3
Poecilus lucasii (Reiche, 1861)				1				1	1
Amara simplex simplex Dejean, 1828									1
Platyderus gregarius Reiche, 1862					2		5	7	11
Calathus opacus Lucas, 1846		7	7	1				1	8
Calathus melanocephalus antoinei Puel, 1939									2
Laemostenus terricola terricola (Herbst, 1784)						1		1	1
Graphipterus exclamationis exclamationis (Fabricius, 1792)									2
Graphipterus luctuosus Dejean, 1825									47
Graphipterus peletieri Laporte de Castelnau, 1840									19
Graphipterus rotundatus Klug, 1832									23
Graphipterus valdanii Guérin-Méneville, 1859									1
Cymindis setifeensis leucophthalma Lucas, 1842									1
Microlestes luctuosus chobauti Jeannel, 1942								1	1
Syntomus fuscomaculatus (Motschulsky, 1844)	1		1				1	1	4
	1	7	8	2	2	1	6	13	125

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