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Diversity of ground beetles in Tikjda forest, Algeria

Разнообразие жуков-жужелиц в лесу Тикжда, Алжир

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Ключевые слова: Carabidae, разнообразие, сезонность, распространение, Тигунатин, лес, Алжир.

Abstract. This paper presents the first data concerning the ground beetles assemblages associated with *Pinus nigra mauretanica* (Maire & Peyerimhoff, 1927) reserve, Djurdjura southerner, Algeria. Carabids were sampled from two sites which differ in their structural vegetation, site No. 2 being more disturbed and more open than site No. 1. As a result of this survey, 231 carabid beetles belonging to 32 species were collected, of which 53.12 % were common to both sites, while 37.50 % and 9.37 % were restricted to site No. 1 and site No. 2 respectively. Diversity indexes were higher in site No. 1. Statistical analysis showed a significant influence of vegetation type on the specific richness of carabid beetles. Disturbances and structural habitat parameters seem to be the major drivers structuring ground beetles assemblages and influencing species abundance, diversity and richness. Carabid richness and abundance in the studied area are lower in disturbed environments and higher when the forest vegetation cover is developed. Adaptive parameters of species, such as diet and seasonal distribution, showed that 57 % of the species (174 individuals) caught are predatory. Two activity periods of ground beetles were noted, the first one occurred in spring and early summer while the second was mainly autumnal. Our results showed the efficiency of pitfall trapping with 70 % of captured individuals and 38 % of carabid species. Among these taxa recorded in the two sites of *Pinus nigra mauretanica* reserve, six species have protected status in Algeria, *Carabus* (*Macrothorax*) *morbillosus, Eurycarabus famini, Laemostenus algerinus, Calosoma inquisitor, Calosoma sycophanta* and *Sphodrus leucophthalmus*, and four were endemic to North Africa, *Calathus fuscipes algiricus, Calathus opacus, Carabus* (*Macrothorax*) *morbillosus* and *Bembidion fluviatile unctulum*. According to the IUCN categories, four species are in danger of extinction, *Sphodrus leucophthalmus, Chlaenius velutinus, Bembidion fluviatile unctulum* and *Brachinus sclopeta*, four are very rare but without current endangerment, *Agonum nigrum, Harpalus attenuates, Notiophilus biguttatus* and *Trechus obtusus,* and two were strongly endangered, *Calosoma inquisitor* and *Calosoma sycophanta*. Three bioindicator species of forest quality were found, *Calathus opacus, Carabus* (*Macrothorax*) *morbillosus* and *Notiophilus biguttatus*.

Резюме. В настоящей работе представлены первые данные о сообществах жужелиц, приуроченных к заповеднику для *Pinus nigra mauretanica* (Maire et Peyerimhoff, 1927) (Южаная Джурбжура, Алжир). Пробы жужелиц были отобраны на двух участках, различающихся по растительности, причём участок № 2 более нарушен и открыт, чем участок № 1. В результате этого фаунистического исследования был собран 231 экземпляр жуков-жужелиц, принадлежащих к 32 видам, из которых 53,12 % были общими для обоих участков, а 37,50 % и 9,37 % были ограничены только участками № 1 или № 2 соответственно. Показатели разнообразия выше были на участке № 1. Статистический анализ показал значительное влияние типа растительности на видовое богатство жужелиц. Эти данные свидетельствуют о том, что нарушения и структура среды обитания, по-видимому, являются основными факторами, определяющими структуру сообществ жужелиц и влияющими на численность, разнообразие и богатство видов. Богатство и обилие жужелиц в рассматриваемой местности ниже в нарушенных условиях и выше при развитом лесном растительном покрове. Адаптационные параметры видов, такие как рацион питания и сезонное распределение, показали, что более половины пойманных видов являются хищниками (57 % или 174 особи). Отмечено два периода активности жужелиц, первый приходился на весну и начало лета, а второй был преимущественно осенним. Наши результаты показали эффективность отлова 70 % экземпляров и 38 % видов жужелиц. Среди этих таксонов, отмеченных на двух участках заповедника для *Pinus nigra mauretanica*, мы отмети-

ли виды, имеющие особый статус: шесть с охраняемым статусом в Алжире [Boutefllka, 2012]: *Carabus* (*Macrothorax*) *morbillosus*, *Eurycarabus famini*, *Laemostenus algerinus*, *Calosoma inquisitor*, *Calosoma sycophanta*, Sphodrus *leucophthalmus*, четыре — эндемика Северной Африки [Boukli et al., 2012]: *Calathus fuscipes algiricus*, *Calathus opacus*, *Carabus* (*Macrothorax*) *morbillosus*, *Bembidion fluviatile unctulum*. Согласно категориям МСОП, описанным Клайбером и др. [Klaiber et al., 2017] мы обнаружили четыре вида, находящихся под угрозой исчезновения: *Sphodrus leucophthalmus*, *Chlaenius velutinus*, *Bembidion fluviatile unctulum*, *Brachinus sclopeta*, четыре очень редких вида, не находящихся под угрозой исчезновения: *Agonum nigrum*, *Harpalus attenuates*, *Notiophilus biguttatus*, *Trechus obtusus* и два сильно угрожаемых вида: *Calosoma inquisitor*, *Calosoma sycophanta*. Обнаружены три вида-биоиндикатора качества леса [Brustel, 2012]: *Calathus opacus*, *Carabus* (*Macrothorax*) *morbillosus* и *Notiophilus biguttatus*.

Introduction

Ground beetles (Carabidae, Coleoptera) is one of the most diverse and studied insect families [Holland, 2002]. They are well known and very diverse taxonomically and ecologically [Avgin, Luff, 2010; Koivula, 2011]. A diversity of 40.000 species of ground beetles was described [Desender et al., 1994; Lövei, Sunderland, 1996], this mainly concerned the temperate areas, as surveys are rarely conducted in the souther hemisphere [New, 1998]. The group is well-documented in the norther hemisphere [Thiele, 1977]. Lövei and Sunderland [1996] reported that ground beetles are distributed over broad geographic ranges and inhabit all major habitats, except the driest parts of deserts. Carabids are abundant in a variety of environments including primary and secondary forests, more generally, carabids were reported to prefer mountainous regions with cool and humid microclimates [Avgin, Luff, 2010].

Carabids have been widely and successfully used for different kinds of studies: they are a crucial component of predator diversity both in natural and agricultural ecosystems [Thiele, 1977; Desender et al., 1994; Holland, Luff, 2000]. Lövei and Sunderland [1996] reported that most carabids are predatory, Bousquet [2010] found that a large proportion of carabid species are omnivorous, consume both animal and plant materials and most species do not show a specialization in their diet, they are opportunist and feed on what invertebrates are available (mites, spiders, caterpillars, ants, aphids, springtails and beetle eggs, larvae and pupae), however, some species tend to specialize in their choice of prey. Several ground beetles are also phytophagous [Bousquet, 2010], granivorous: eg. those eating the seeds of herbaceous plant and may be an important factor in weed control [Honek et al., 2003], or polyphagous [Holland, Luff, 2000].

Carabids are known to be highly sensitive to environmental disturbances [Butterfield et al., 1995; Gobbi, Fontaneto, 2008], to which they react by different ways such as changes in species number or abundance [Niemelä, 2001; Rainio, Niemelä, 2003; Scalercioe et al., 2009] and changes in abundance, diversity, community structure and composition [Niemelä et al., 1993].

Due to their sensitivity, ground beetles are useful model organisms, used as bioindicators [Rainio, Niemelä, 2003; Koivula, 2011]. In forests, carabids respond quickly to environmental factors such as temperature, humidity, vegetation, size of the forest patch [Eyre, Luff 1990; Niemelä, 2001], cover of forest canopy or plant diversity [Lange et al., 2014] and anthropogenic disturbances [Thomas et al., 2002].

The Djurdjura Mountain accounts among the main old forests of the Mediterranean [Quézel, Medail, 2003] and it is part of the biodiversity hotspots of the Mediterranean basin [Véla, Benhouhou, 2007]. Despite its inclusion in a protected area (i.e. as a National Park since 1983 and as a biosphere reserve since 2007), this Mountain is subject to deep anthropogenic disturbances as pointed out by Quézel and Medail [2003].

In Algeria, carabid beetles are still relatively poorly known and the research on this family only started recently, there are limited information available concerning carabid community composition in forest areas: there is one published study in in the National Park of Chrea, Atlas of Blida [Belhadid et al., 2013] and some works in agricultural areas [eg. Saouache et al., 2014].

The present study aimed to investigate, for the first time, the spatial variability in abundance and species richness of Carabidae in two sites of the *P.nigra mauretanica* reserve (Tikjda forest, Tigounatine reserve, Djurdjura southerner).

Material and methods

Study area. The study site is located in the Tikjda forest area (Djurdjura southerner). The forest covers are dominated by *Quercus ilex* in the lower range and *Cedrus atlantica* in the upper range while these two major species are intimately mixed in their contact zones with *Q. ilex* dominating on thermophilous slopes and *C. atlantica* dominating on mesic ones. Besides the forest covers there are also large open areas which resulted from forest degradation (Fig. 1).

Tigounatine stand accounts among the forest patches of Tikjda forest area. In this area *P. nigra mauretanica* occupied, until summer 2012, three patches (i.e. Tikjda-centre, Taouielt and Tigounatine) distant from each other by a linear distance of 1.2 to 1.5 km and comprising unequal numbers of individuals: 450 at Tigounatine, 20 at Taouielt and 11 at Tikjda-centre of which 4 ones were burned following the fire of 2000. The portion of Tigounatine forest comprising *P. nigra* has been fenced in the 1980s and is so-called «the *P. nigra* Tigounatine reserve» (36°27'06" and 36°27'20" N; 04°06'19" and 04°06'46" E). Two sites of this reserve are presently investigated carabid diversity. The two sites share the altitudinal range (1500–1650 m), the terrain aspect (i.e. North), the geological substratum (i.e. limestone), the soil type, i.e. rendzina

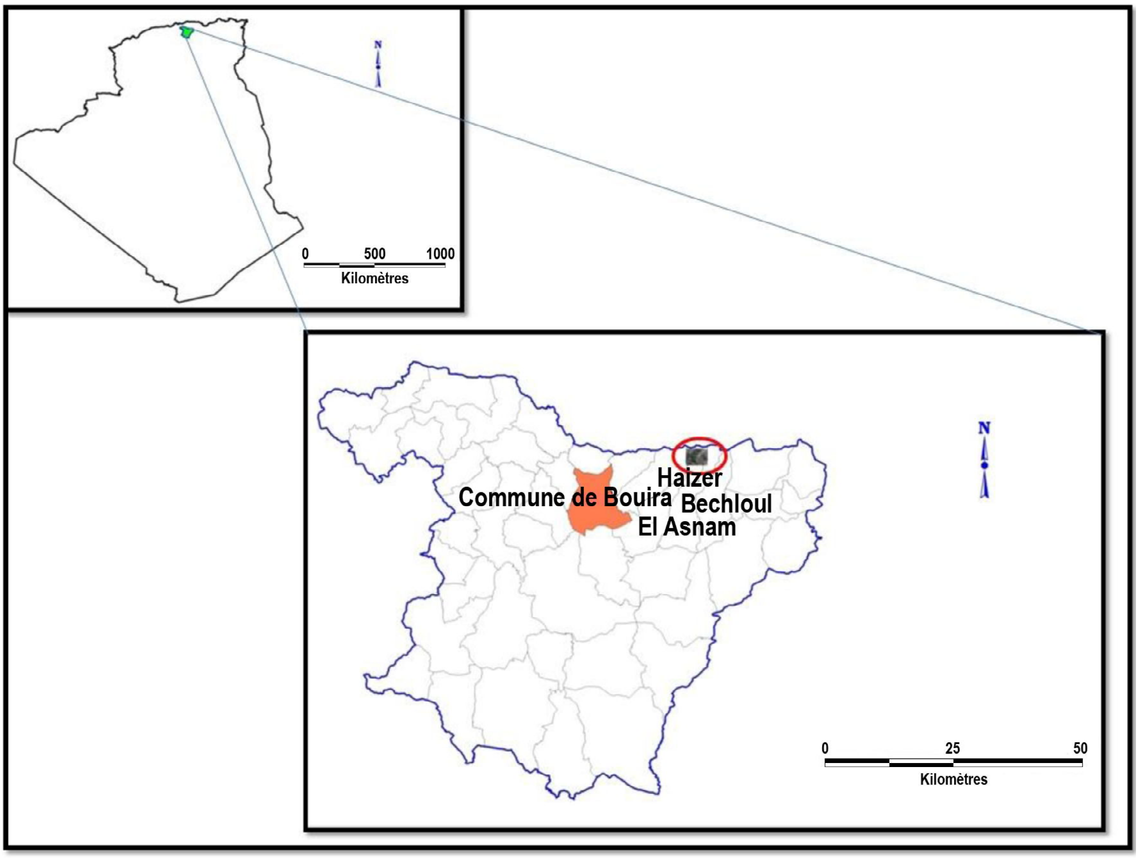

Fig. 1. Location of the study site at the scale of Algeria (Google Maps).
Рис. 1. Расположение места исследования в Алжире (Google Maps).

with A/C soil type [Benmouffouk, 1995], the bioclimate, i.e. humid with cool winters [Benmouffouk, 1995], the floristic group i.e. the *Juniperotosum hemisphericae* a component of the *Senecio-perralderiani-cedretum atlanticae* [Quézel, Barbero, 1989] but they differ by structural vegetation attributes: site No. 1 consists mainly of old *C. atlantica* trees and few *Q. ilex* in the upperstorey and large cushions of the prostrate common juniper «*Juniperus communis hemisphaerica* (C. Presl) Arcang, 1882» in the understorey. Site No. 2 consists mainly of *P.nigra mauretanica* in mixture with scattered *C. atlantica* and *Q. ilex* trees in the overstorey and shrubs of cade juniper «*Juniperus oxycedrus rufescens* Link, 1846» in the understorey. Regarding microclimatic conditions, site No. 2 is more open than site No. 1. Indicators of past disturbances (logs, snags and fallen dead wood) were found in site No. 2.

Insect sampling. For each sampling visit, twenty (20) stations were chosen randomly in *P. nigra mauritanica* reserve; ten (10) stations in site No. 1 and (10) others in site No. 2. We sampled in both sites previously described. Here, we studied the ground beetle fauna for one year using 5 sampling methods (Pitfall traps, sweeping, beating, colored traps and the aerial attractive traps) per site (first opened 01 March 2017; closed 5 March 2018). Samples were collected every 15 days.

In each site, ten (10) pitfall traps [Barber, 1931] were arranged in a straight line and spaced five meters from each other. Each pot was half filled with water to which we added few drops of liquid soap and few grams of salt. Ten (10) sweeps per tree canopy with to and from movements were carried out using a net of 38 cm diameter and dense sailcloth mesh to carry out the sweeping method, ten (10) trees per site were swept, the net was sprayed lightly with a knockdown non persistent insecticide to allow easy transfer of insects into plastic boxes. Beating consisted of a white net of 120 x 120 cm stretched on a folding wooden frame and introduced under the foliage of trees and shrubs while the plants are shaken roughly (beating). Ten (10) coloured traps (yellow traps) were attached directly to the branches of 10 trees in each site, the attracted insects fall into the trap which contains a brine with a detergent (liquid soap). Ten (10) plastic bottles (1.5 liter) were hung with a hook on the high branches of ten trees in site No. 1 and ten others in site No. 2. The bottles were filled with soapy water and two lateral openings (about 6 x 6 cm) allow insects to fly in the bottles. The captured specimens were sorted, labeled, preserved in 70 % alcohol and identified in the laboratory under a compound binocular microscope (EZ4, LEICA) following the classification of Löbl and Löbl [2017] with the aid of keys [Antoine, 1955, 1957, 1959, 1961, 1962].

Some species were identified and confirmed by professor Gahdab Chakali, entomologist at the laboratory of zoology (ENSA, Algiers, Algeria) and by professor Hervè Brustel, director of the environmental sciences and biodiversity department at the Purpan Engineering School (INPT, Toulouse, France).

Data analysis. Ecological indices such as total abundance, species richness, frequencies, the Shannon diversity index *H'* [Shannon, 1948], maximal Diversity and the Equitability index *E* [Pielou, 1966] were used in order to characterize and compare the degree of community complexity of ground beetles species in prospected sites. In addition, Pearson's Chi-squared test was used to determine if the type of vegetation influences the specific richness of carabid beetles and an analysis of Deviance table by a GLM (general linear model) was performed to know if insect effectives (number of individual) are the same according to the type of vegetation. All the data were analyzed using the R software.

In order to determine the trophic structure of carabids in *P. nigra mauretanica* reserve, we focused only on diet of adults captured. The following documents were consulted: Thiele [1977], Dethier [1985], Lövei and Sunderland [1996], Velle [2004], Bousquet [2010]. To determine the status of the captured species as well as their patrimonial values, the following papers were consulted: Boukli et al. [2012], Bouteflika [2012], Brustel [2012], Klaiber et al. [2017].

Results

Composition of the carabid fauna

During the year cycle, 231 specimens of ground beetles were caught and 32 species distributed among 23 genera were identified. 156 individuals representing 29 species and 75 others belonging to 20 species were registered respectively in site No. 1 and site No. 2 (Tab.1).

Specific richness, abundance and species diversity

The diversity of carabofauna in *P. nigra mauretanica* reserve showed that seventeen species (i.e. 53.12 % of the total richness) were present in both sites, while thirteen ones (i.e. 46.88 % of the total) were restricted to one site with twelve (12) species (i.e. 37.50 %) sampled only in site No. 1 and three (03) species (i.e. 9.37 %) (*Amara convexa, Brachinus sclopeta* and *Sphodrus leucophthalmus)* observed only in site No. 2.

Among the 32 genera censused, the genera *Carabus* Linnaeus, 1758 and *Calathus* Bonelli, 1810 were represented by 3 species each, the genera *Syntomus* Hope, 1838, *Harpalus* Latreille, 1802, *Laemostenus* Bonelli, 1810, *Syntomus* Hope, 1838, *Calosoma* Weber, 1801 and *Zabrus* Clairville, 1806 were represented by 2 species each, while each of the other genera were represented by a single species.

Regarding the species abundance, *Carabus morbillosus* is the most abundant species in both sites with 18.55 % of the total richness (i.e. 41 individuals) followed by *Calathus fuscipes algiricus* with 11.33 % (i.e. 25 individuals).

Among these taxa recorded in the two sites of *P.nigra mauretanica* reserve, we noted species that have a remarkable status: six (6) with protected status in Algeria [Bouteflika, 2012]: *Carabus* (*Macrothorax*) *morbillosus, Eurycarabus famini, Laemostenus algerinus, Calosoma inquisitor, Calosoma sycophanta, Sphodrus leucophthalmus*, four (4) endemic to North Africa [Boukli et al., 2012]: *Calathus fuscipes algiricus, Calathus opacus, Carabus* (*Macrothorax*) *morbillosus, Bembidion fluviatile unctulum*. According to the IUCN categories described in Klaiber et al. [2017], we have found: four (4) species in extinction danger: *Sphodrus leucophthalmus, Chlaenius velutinus, Bembidion fluviatile unctulum, Brachinus sclopeta*, four (4) very rare species without current endangerment: *Agonum nigrum, Harpalus attenuates, Notiophilus biguttatus, Trechus obtusus* and two (2) species strongly endangered: *Calosoma inquisitor, Calosoma sycophanta*. Three (3) bioindicator species of forest quality were found [Brustel, 2012]: *Calathus opacus, Carabus* (*Macrothorax*) *morbillosus, Notiophilus biguttatus.*

Regarding the diversity and equitability, site No. 1 seems to be more diverse ($H' = 4.53$) and more balanced (0,94) than site No. 2 (Tab. 2).

The Pearson's C hi-squared test showed a significant influence of vegetation type (of sites No. 1 and No. 2) on the number of carabid species recorded (Tab. 3).

Analysis of Deviance Table by a GLM (general linear model) showed a significant difference in carabid numbers (number of individuals) between the two studied sites (Tab. 4).

Traits of the species

Trophic structure. The carabids found in *P. nigra mauretanica* reserve form five trophic groups (phytophagous, granivorous, omnivorous, predator and zoophagous). More than half of this diversity were predators (57 % of species and 60 % of individuals). Six (6) species and 12 % individuals were phytophagous. The omnivorous and granivorous were represented by four (4) species each, while zoophagous were the less presents (two species and 2 % individuals) (Fig. 2).

Sampling methods. Among the diversity of ground beetles caught, the most number of individuals (70 %) and species (i.e.26 species) were trapped with pitfall trapping. 14 % and 10 % specimens belonging to 18 and 11 species were captured respectively with beating and aereal attractive traps while only 3 % individuals were found with sweeping and coloured traps (Fig. 3).

Seasonal distribution. The seasonal distribution of ground beetles showed two activity periods. The first occurred in spring and early summer, while the second was autumnal, between the two activity periods few adults were trapped. In winter, there were almost non ground beetles (Tab. 5).

Table 1. Ground beetles species and individual number captured in *P. nigra mauretanica* reserve, with the diet of adult species, their status and their patrimonial values

Таблица 1. Видовой состав и численность жужелиц, отловленных в заповеднике для *P. nigra mauretanica*, с трофическими связями, охранным статусом, с рационом взрослых особей, их статусом и родовым значением

Taxons	Phytophagous	Granivorous	Omnivorous	Predator	Zoophagous	Patrimonial values	Status of species (IUCN)	Total individuals No. S1	Total individuals No. S2	Total individuals
Agonum nigrum (Dejean, 1828)			x	x			(LC)	5	3	8
Amara convexa (Leconte, 1848)	x	x						0	4	4
Brachinus sclopeta (Fabricius, 1792)				x			(CR)	0	2	2
Calathus circumseptus (Germar, 1823)				x			(RE)	4	0	4
Calathus fuscipes algiricus (Gautier des Cottes, 1866)			x	x		EAN		15	10	25
Calathus opacus (Lucas, 1846)				x		BI, EAN		3	0	3
Carabus (Macrothorax) morbillosus (Fabricius, 1792)				x		PA,BI, EAN		25	16	41
Carabus famini (Dejean, 1826)				x				7	4	11
Carabus sp.				x				4	2	6
Eurycarabus famini algerinus (Fairmaire, 1859)				x		PA		8	0	8
Harpalus attenuatus (Stephens, 1828)	x	x					(LC)	10	5	15
Harpalus wohlberedti (Emden et Schauberger, 1932)	x	x						6	2	8
Laemostenus barbarus (Lucas, 1846)				x				9	0	9
Laemostenus algerinus (Gory, 1833)						PA		2	4	6
Licinus punctatulus (Fabricius, 1792)				x				3	0	3
Microlestes corticalis (L. Dufour, 1820)				x				7	0	7
Nebria andalusiaca (Rambur, 1837)				x				2	3	5
Notiophilus biguttatus (Fabricius, 1779)					x	BI	(LC)	3	0	3
Parophonus hespericus (Jeanne, 1985)	x		x					2	0	2
Pterostichus sp (Bonelli,1810)			x	x				6	0	6
Syntomus barbarus (Puel, 1938)				x				5	5	10
Syntomus fuscomaculatus (Motschulsky, 1844)				x				2	2	4
Trechus obtusus (Erichson, 1837)					x		(LC)	3	1	4
Calosoma inquisitor (Linnaeus, 1758)				x		PA	(EN)	2	0	2
Calosoma sycophanta (Linnaeus, 1758)				x		PA	(EN)	3	0	3
Bembidion fluviatile unctulum (Antoine, 1941)				x		EAN	(CR)	2	3	5
Chlaenius velutinus (Duftschmid, 1812)				x			(CR)	7	2	9
Zabrus jurjurae (Peyerimhoff, 1908)	x							3	0	3
Zabrus farctus (Zimmermann, 1831)	x							2	1	3
Dixus sphaerocephalus (Olivier, 1795)		x						5	2	7
Sphodrus leucophthalmus (Linnaeus, 1758)				x		PA	(CR)	0	3	3
Orthomus aquila (Coquerel, 1859)								1	1	2

Notes. PA: Protected in Algeria, EAN: Endemic of North Africa; Between brackets: IUCN category in Klaiber et al. [2017]; (LC): very rare species without current endangerment; (CR): extinction danger; (RE): extinct in Switzerland; (EN): strongly endangered.

Примечание. PA: охраняется в Алжире, EAN: эндемик Северной Африки; В скобках: категория МСОП по Klaiber et al. [2017]; (LC): очень редкий вид, не находящийся под угрозой исчезновения; (CR): вид находится в опасности исчезновения; (RE): вымершие в Швейцарии; (EN): находящийся под угрозой исчезновения.

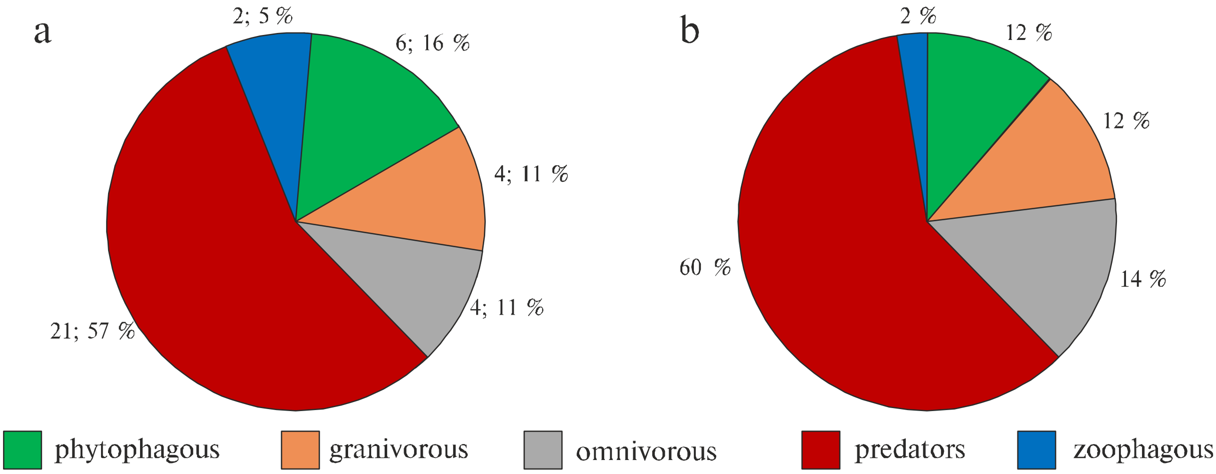

Fig. 2. Diet of carabid adults captured in *P. nigra mauretanica* reserve. (a): number and percentage of species, (b): percentage of individuals.

Рис. 2. Рацион взрослых жужелиц, отловленных в заповеднике для *P. nigra mauretanica*. (a): количество и процентное содержание видов, (b): процент особей.

Discussion

Specific richness, abundance and species diversity of carabid beetles are interesting for this research because they had previously only rarely been investigated under biodiversity aspects in the Mediterranean area, yet they are a frequently studied group of indicators elsewhere. Our data on species diversity suggest that Carabidae assemblages are distinct across sites as mentioned by Thiele [1977]. These caught species were dominated by *Carabus* (*Macrothorax*) *morbillosus*, followed by *Calathus fuscipes algiricus*. This later was the most represented species of Carabidae in the cedar forest of Chrea National Park (Blida, Algeria) [Belhadid et al., 2013].

The abundance and number of the species recorded were higher in site No. 1 than site No. 2, this could be related to the forest canopy cover [Magura et al., 2002; Cividanes et al., 2010], organic matter [Jukes et al., 2001; Magura et al., 2002], leaf litter [Magura et al., 2002] and anthropogenic disturbances [Thomas et al., 2002].

In site No. 1, the canopy cover ensured by aged Atlas cedar trees combined with the ground cover provided by the larger cushions of common juniper seem to have a positive effect on diversity and abundance of carabid beetles by providing them favourable conditions regarding the availability of plant debris, vegetation, wood, organic matter, food, shelter and leaf litter.

In contrast, the lower vegetation cover in site No. 2 can increase the exposure to climatic hazards: vegetation cover attenuate and/or delay climatic fluctuations

Table 2. Shannon diversity index (*H'*) and Equitability index (*E*) in the two sites of P. *nigra mauretanica* reserve

Таблица 2. Индекс разнообразия Шеннона (*H'*) и индекс выравненности (*E*) на двух участках заповедника для *P. nigra mauretanica*

Sites	H' [bits]	E
Site No.1	4.53	0.94
Site No. 2	3.88	0.7

Table 3. Results of the Pearson's Chi-squared test on the number of carabid species between two microsites

Таблица 3. Показатели критерия согласия Пирсона для количества видов жужелиц между двумя местообитаниями

Chi-squared	df	p-value
40.021	19	0.003251

Table 4. Results of the GLM (general linear model) test on the number of individuals per species between the two microsites

Таблица 4. Результаты теста GLM (основная линейная модель) по количеству особей на вид между двумя местообитаниями

Chi-squared	df	p-value
15.50	1	0.000008

Table 5. Seasonal distribution of individual number caught in *P. nigra mauretanica* reserve

Таблица 5. Сезонное распределение численности особей, пойманных в заповеднике для *P. nigra mauretanica*

Season	Individual number	
	Site No. 1	Site No. 2
Summer	45	20
Autumn	59	28
Winter	4	3
Spring	50	24

on a small time scale (daily) as well as on a larger scale (annual) as was found by Tenailleau et al. [2011].

Our findings concord with Thomas et al. [1992], Butterfield [1997] and Honek and Jarosik [2000] who found that the distribution of beetles is strongly related to the density of vegetation cover and habitats with dense vegetation cover being characterized by higher species richness [Magura et al., 2001; Standberg et al., 2005]. In fact, when vegetation density is higher, the soil relative humidity level remains high for a longer period of time [Lalonde, 2011] which promotes a greater abundance of carabids [Kromp, 1989; Cardwell et al., 1994].

On another hand, leaf litter which is more abundant in site No. 1 is beneficial to Carabidae and their larvae and may be advantageous for egg-laying and can influence microclimatic conditions (lower ground temperature, higher amount of prey items) and produce favourable microhabitat conditions that could influence the spatial distribution of ground beetles as mentioned by Magura et al. [2004].

Site No. 2 was more disturbed and could cause a less favourable habitats for ground beetles as found by Magura et al. [2004] and Moraes et al. [2013]. Opposing, Silva et al. [2008] assessed the diversity of disturbed areas in a Mediterranean climate and found that the highest species richness and abundance of terrestrial beetles were recorded in extremely and frequently disturbed areas.

Ground beetles are known to exhibit preferences for a limited range of factors such as moisture, temperature, shade and soil parameters [Thomas et al., 2002], light levels and other abiotic factors [Thomas et al., 2002] that can affect their abundance and distribution as pointed out by Thiele [1977] and Koivula et al. [2004]. Carabids also move quickly to escape bad conditions [Pena, 2001]. Indeed, ecological requirements of carabids vary and, consequently, some species are more sensitive to environmental conditions than others as pointed out by Niemelä et al. [1993].

In this study only 46.88% of species were common to both sites, while 40.62 % and 9.38 % were restricted only to sites No. 1 and No. 2 respectively. This suggests that differences in local ecological factors between studied sites may influence abundance of carabid species. At the community level, habitat selection criteria are linked to biotic factors whose combinations describe how species share space by creating different ecological niches.

The value of equitability index in site No. 1 is close to 1, suggesting a relative equilibrium of this microhabitat and a balance in the distribution of species abundances. Conversely, the lower values of Shannon diversity index ($H' = 3.88$) and Equitability index ($E = 0.7$) in site No. 2 suggest species of this group to not be in equilibrium with each others and with their environment.

Pearson's Chi-squared test showed a significant influence of the vegetation type on the number of carabid species sampled, concordantly the GLM procedure showed a significant difference for the number of carabids (individual number) between the two studied sites.

Sampling methods. Regarding sampling methods, pitfall trapping caught the highest number of species and individuals (26 species and 70 % individuals). Lövei and Sunderland [1996] reported that pitfall trapping is the most frequently used field method, it is effective for walking epigean carabidae [Bouget et al., 2009] because carabids can be easily and cost-effectively collected [Avgin, Luff, 2010; Lott et al., 2011]. This method is successfully applied by many authors [Butterfield, 1997; Holland, 2002; Thomas et al., 2002; Avgin, Luff, 2010; Gwiazdowicz, Gutowski, 2012; Saouache et al., 2014; Pizzolotto et al., 2018; Ganaoui et al., 2019].

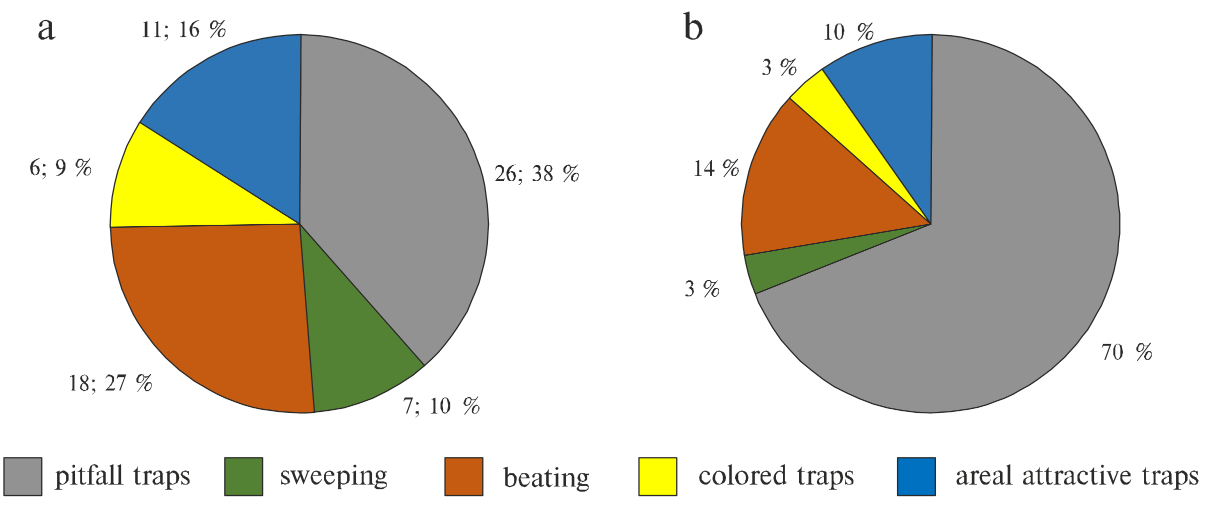

Fig. 3. Sampling methods of carabid adults captured in *P. nigra mauretanica* reserve. (a): number and percentage of species, (b): percentage of individuals.

Рис. 3. Методы сбора имаго жужелиц, отловленных в заповеднике с сосны *P. nigra mauretanica*. (а): количество и процентное соотношение видов, (б): процентное соотношение особей.

The absence of six Carabidae species in pitfall trapping could be due to active flight dispersal and low walking ability for these species as mentioned by Bouget et al. [2009].

To estimate the carabofauna using pitfall trapping, we used twenty (20) pitfall traps, Stein [1965], showed that semi-dominant and rare species could be caught with only five (5) pitfall traps, Bouget et al. [2020] reported that ten (10) to twelve (12) pitfall traps are sufficient to estimate species abundance. For his part, Mehenni [1994] demonstrated that the quantitative data did not change when the number of traps is twenty (20).

Most previous studies on the efficiency of different methods were conducted in temperate climate regions of Europe and North America [e.g. White, 1998; Lott et al., 2011]. Timm [2010], reported that for the Mediterranean region, there have been no studies which deal with the efficiency of pitfall traps and other methods of collecting ground beetle assemblages.

Lott et al. [2011] found that many of carabid beetles could be collected using traditional techniques such as sweeping and beating vegetation. As for White [1998], he reported that these methods are very effective way to catch beetles that feed on plants or prey on plant-eating insects, or beetles using foliage or flowers. In our study, beating captured more species than sweeping (eighteen and seven species respectively), it may be due to the umbrella or sheet which has more surface than a sweep net, so the beetles from a large mass of foliage can be knocked into it with one stroke, in addition, where the plants are tough and scrubby, an umbrella or sheet works better than a sweep net as mentioned by White [1998].

The coloured traps are based on the visual attraction of colors (imitating those of flowers) for heliophilic and floricolous insects [Bonneil, 2009]. In our case, only three carabids were found in the yellow traps. So, it seems to be the least effective method for the capture of ground beetles. Eleven species and 10 % individuals were caught using the aerial attractive traps, Allemand and Aberlenc [1991] reported that these traps are used for studying the insect fauna of the tree canopy in temperate area.

Moreover, the catch rate for epigeic species depends on the «environmental resistance» caused by the vegetation structure which obstructs the beetles in their locomotor activity [Heydemann, 1955]. The physiological condition of the animals also has an effect on the intensity of locomotor activity and thus also on the catch rates [Chiverton, 1984].

Carabids diet. Among the five trophic groups found in our study, there were more predators (57 % species and 60 % individuals), like *Macrothorax morbillosus* which is the most dominant species and *Licinus punctatulus.* According to Dajoz [2002] and Ouchtati et al. [2012], these two species are specialized for feeding on molluscs. *Calosoma inquisitor* is also a generalist predator species feeding on the larval and pupal stages of the oak processionary (*Thaumetopoea processionea*, Lepidoptera notodontidae) which causes devastation in forests [Baker et al., 2009]. Several authors [Kromp, 1999; Holland, Luff, 2000; Bouget et al., 2009] reported that many species of ground beetle family are predators of other arthropods.

The number of predators was higher in site No. 1, among the 227 predatory individuals caught, 68/72 % and 31,28 % were found respectively in site No. 1 and site No. 2, this may be due to marked disturbances in site No. 2. According to several authors [Kotze, O'Hara, 2003; Brandmayr et al., 2005; Lovei, Magura, 2006], predators are negatively affected by habitat disturbances.

Marino and Landis [1996], Samu [2003] reported beneficial effects of vegetation cover on the diversity and presence of predatory and phytophagous insects, in our case, we caught six phytophagous species. Among the 32 carabids captured, four species were granivorous, Bouget et al. [2009], reported that some genera (eg. *Amara* and *Harpalus*) being at least partially granivorous and phytophagous.

For his part, Thiele [1977] reported that carabids are mostly polyphagous feeders that consume animal (live prey and carrion) and plant material, and several species are phytophagous.

Seasonality. In our study, the first period of ground beetles marked in spring-early summer could be devoted chiefly to breeding while the second one (automnale) was devoted largely to feeding as mentioned by Bousquet [2010] for temperate and boreal carabids.

The two peaks could be explained by the coincidence with the development of soil dwelling arthropods and their larvae which constitute prey for carabids as found by Chen and Willson [1996] in soybean ecosystems.

The almost total absence of ground beetles in winter season could be explained by weather conditions, it snows and the temperatures are very low, so, carabids were in their dormant period. Lövei and Sunderland [1996], reported that seasonal rhythms involving dormant periods during winter and / or summer (aestivation) are an integral part of the life history of temperate-region ground beetles. Our finding concord with Tenailleau et al. [2011], who found that carabid adults realize a diapause, they then search a «stable» overwintering refuges and wait for favorable conditions to colonize the crops.

Loreau [1978] reported that in forest, the overwintering species at the larval stage are more present, these species having a later annual activity (summer / autumn). Tenailleau et al. [2011], found that the peaks of carabids activity are consequently shifted in time because forest warms and cools later in the year than grassland.

Seasonal weather conditions, such as temperature and precipitation influenced carabid species and abundance as pointed out by Chen and Willson [1996]. Kegel [1990] pointed out that daily rhythm of activity of many species of Carabidae is related to soil temperature, as for Tenailleau et al. [2011], they noted that the duration of larval development for the different stages increases as the temperature decreases.

Timm [2010] reported that in contrast to the temperate zones, little research has been done on the annual cycles of ground beetles in the Mediterranean climate region.

Conclusion

As a result of a faunistic survey on Ground beetles which was conducted in two sites within the *P.nigra* mauretanica reserve of Tigounatine (Tikjda forest, Djurdjura), 231 individuals representing 32 species were captured. Our research revealed that site No. 1 hosted the higher diversity of ground beetles than site No. 2. Thus, species richness, abundance and Shannon diversity indices were higher in site No. 1.

The results showed that the richness and abundance of Carabidae depend on a complex set of environmental factors, the canopy covers of aged Atlas cedar trees combined with the ground cover ensured by common Juniper cushions appeared to have a positive effect on ground beetles diversity by providing them favourable conditions. In contrast, where the vegetation cover is poor, species are more exposed to climatic hazards. In addition, it appears that carabids abundance and diversity are lower in disturbed area.

Traits of species, like diet and seasonal distribution revealed the existence of five trophic groups with dominance of predatory species. Indeed, the two sites of this forest, by their structure, the great diversity of their facies, their bioclimates and the quality of their soils allow the installation of a fauna likely to be the prey to these groups of insects.

The spatial distribution of carabid abundance and species richness varied seasonally, and the higher abundances were registered on spring and early summer and on autumn. It appears that seasonal weather conditions were the major factors influencing carabid species richness and abundance from season to season. Also, we hypothesized that annual cycles of each species of ground beetles may be related to the amount of food available.

Pitfall trapping caught the higher number of species and individuals, perhaps because the majority of the caught species were walking epigean carabidae.

Our results suggest that analyses of carabids assemblages could be helpful in forest ecological studies to determine habitat stability and local site conditions could be drivers of carabid diversity. More long-term and periodic surveys could provide new records of Carabid species. Additional efforts must be carried out to obtain more information about the spatiotemporal distribution of carabid species in other mountain forest covers and other ecosystem areas.

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