

Ground beetle communities (Coleoptera, Carabidae) of Holm oak-forests (*Quercus ilex*) and their degradation stages on Mallorca (Iles Balears, Spain)

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Ground beetles (Coleoptera: Carabidae) were examined in the Serra de Tramuntana (Mallorca). These beetles serve as ecological indicators to describe effects of human impact in terrestrial habitats and are used in nature conservation. There were analysed holm oak (*Quercus ilex*) forest sites as well as garrigue sites in former oak forest areas. A total of 17 Carabid species with 1810 individuals was recorded. One species, *Pseudomasoreus canigoulensis*, was found first time on the Balearic islands. The species numbers per site varied between 2-6 in forests and 5-10 in garrigues. Despite the lower species number, the forest sites had more individuals due to a large population density of *Calosoma sycophanta*, a specialized oak forest species. The ground beetle community changes clearly between forest and garrigue in the Serra de Tramuntana despite the fact that both habitat types are located in direct neighbourhood and that both habitat types are shared by many abundant species in other Mediterranean areas (e.g. Greek mountains). We must conclude that the decrease of forest area and forest fragmentation of Mallorca are connected with decrease and possible disappearing of typical (in part endemic) forest Carabidae which do not find secondary habitats in shrubland. Moreover, garrigues are inhabited mainly by wide spread Carabid species as *Acinopus picipes* or *Harpalus attenuatus*.

Keywords: Carabidae, *Quercus ilex* forest, garrigue, ecological indicators.

COMUNITATS DE CARÀBIDS (COLEOPTERA, CARABIDAE) DELS BOSCOS D'ALZINES (*Quercus ilex*) I LES SEVES ETAPES DE DEGRADACIÓ A MALLORCA (ILLES BALEARS, ESPANYA). Han estat estudiades les comunitats de Caràbids (Coleoptera: Carabidae) de distints punts de la Serra de Tramuntana (Mallorca). Aquests escarabats serveixen d'indicadors ecològics per descriure efectes d'impacte humà en hàbitats terrestres i s'utilitzen en la conservació de natura. En aquest article s'han analitzat els boscos d'alzina (*Quercus ilex*) així com zones de garriga situades a zones contigües als alzinars. S'han capturat un total de 17 espècies de Caràbids amb 1810 individus. Una espècie, *Pseudomasoreus canigoulensis*, s'ha capturat per primera vegada a les Illes Balears. El número d'espècies per localitat variaven entre 2-6 en boscos i 5-10 en garrigues. Malgrat el número d'espècies és més baix a zones boscoses, aquestes comptaven amb més individus a causa d'una densitat de població gran de *Calosoma sycophanta*, una espècie d'alzinars especialitzada. La comunitat d'escarabats canvia clarament entre alzinars i garrigues al Serra de Tramuntana, encara que aquests ambients estiguin situats a zones properes comparteixin moltes espècies, algunes d'elles molts abundants, igual que succeeix a altres llocs de la Mediterrània (p. ex. Muntanyes de Grècia). Hem de concloure que la disminució d'àrea de boscana i fragmentació d'hàbitat de Mallorca estan relacionades amb la disminució i la possible desaparició de comunitats de Carabidae forestals (en

part endèmiques) que no es troben a hàbitats secundaris de garrigues. A més, les garrigues estan habitades principalment per espècies de Caràbids d'àmplia distribució com *Acinopus picipes* o *Harpalus attenuatus*.

Keywords: *Carabidae*, *alzinars*, *garrigues*, *indicadors ecològics*.

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Introduction

Holm oak forests (encina, *Quercus ilex* L.) are the natural vegetation of large parts of the West-Mediterranean region including the Balearic islands. Due to human influence these forests disappeared wide-ranging. On Mallorca holm oak stands are restricted to the mountainous areas of the Serra de Tramuntana today. Large areas of former oak forests covered actually by garrigue which is regarded a degradation stage of former forests (Braun-Blanquet, 1928; Le Houerou, 1992; Wagner, 2001).

We do not know much about the invertebrate communities in the soil stratum of Mediterranean oak forests. Therefore, aims of our study are (i) to examine the ground beetle community (Coleoptera: Carabidae) of Mallorcan oak forests and (ii) to analyse the change of these beetle communities after disturbance of oak forests and development of garrigues. The results of this study could give new insights in ecosystem ecology linked to Mediterranean habitat types and useful parameters for nature conservation, e.g. for evaluation of habitats, for habitat monitoring or to define the favourable conservation status of habitats as recommended in the Habitats Directive (European Commission 1992; 2000; 2005).

Carabidae are generally accepted as ecological indicators which are used in

nature conservation survey (see Arndt, 2008 for detailed information) or to describe gradients of human impacts in terrestrial habitats (e.g. Kerr *et al.*, 2000; Pearce & Venier, 2006; Rainio & Niemela, 2003; Thiele, 1977; Stork, 1990). The methodology of this indications system is well developed in Central and Northern Europe as well as North America, where ground beetle studies have a long tradition and produced a huge knowledge and reference list (see compiling references above). However, comparable ecological examinations are still rare in the Mediterranean region (Allegro & Sciaky, 2003; Brandmayr *et al.*, 2005). Therefore we regard this first ecological study of ground beetles assemblages on Mallorca a base for further ecological and nature conservation work in other Mediterranean areas.

Material and methods

Study sites

The examination took place in the Serra de Tramuntana, a mountain region in the West and North part of the island. It represents the Mallorcan main mountains with 13 peaks higher than 1000m a.s.l. Mallorcan holm oak forests are restricted to parts of these mountains nowadays.

We selected four forest plots to study



Fig. 1. *Quercus ilex* forest site F-W2 south of Lluc.

Fig. 1. Localitat d'estudi F-W2 a un alzinar del sud de Lluc.

ground beetles assemblages. The examined forests have an age of about 80-100 years. Each forest plot contained an area of several hectares, the forest structure was more or less homogeneously and soil conditions, bedrock, exposition, altitude and vegetation were comparable between all plots (Fig. 1). The sites are located in the central part of the main mountains between Lluc and the base of the north slope of Puig de Massanella and Turixant de Dalt and the base of north slope of Puig Major respectively.

Beside the forest areas four sites with garrigue vegetation were selected (Fig. 2). All four sites are located inside the former forest belt and must be regarded as degradation stages of the oak forests. Two garrigue sites are directly attached to the

forests sites, two others have a distance of about 400 m to the forest edge. The garrigue sites have in common a shallow soil, sparse or sketchy vegetation less than 1,50m high with typical plants as *Cistus* and *Crataegus*. A detailed description of sites is given in Table 1.

Sample methods

We used pitfall traps to sample the carabid material. At each site five traps (500ml, an opening diameter of 7cm) were set up in the ground. The five traps were arranged in one row with a distance of about 2 m between two traps. One or two stones were placed near the traps to prevent their demolition by grazing goats. This method was successfully tested during a long-time examination in Greek Mediterranean habitats. A 4% solution of formaldehyde served as preservation liquid. The sampling was started April 20, 2006 and completed November 20, 2006. A control of traps and remove of beetles took place every 10 days.

The trap results do not represent the true abundance of carabid species but the "density of activity" because only surface active beetles are captured by pit fall traps.



Fig. 2. Garrigue site G-L south of Lluc.

Fig. 2. Localitat d'estudi G-L al sud de Lluc.

	G-L	F-L	F-W1	F-W2	G-EO	G-EU	F-SC	G-SC
Location	39°48'50.39"N 2°53'12.76"E	39°48'50.48"N 2°53'11.30"E	39°48'54.17"N 2°53'01.00"E	39°49'10.82"N 2°52'31.79"E	39°49'41.39"N 2°50'38.70"E	39°49'43.79"N 2°50'37.13"E	39°49'04.60"N 2°49'04.74"E	39°49'04.50"N 2°49'09.19"E
Altitude a.s.l.	666m	673m	665m	702m	611m	597m	625m	603m
Exposition	NE	NNE	N	NE	N	N	NE	NE
Inclination	15°	25°	15°	25°	5°	0	25°	10°
Total coverage with vegetation (%)	60	85	90	90	55	45	90	60
Tree layer	0	1	1	1	0	0	1	0
Shrub layer	1	0	1	1	1	0	0	1
Herb layer	1	0	0	0	1	1	1	1
Coverage of ground with mosses (%)	8	15	5	40	1	1	1	5
Leaf litter (cm)	0	1	1	1	0	0	2	0
Surface coverage with stones (%)	20	50	5	45	28	30	65	10
Maximum height of trees or shrubs	<1m	20-2 m	16-18m	16-18m	<2m	<2m	18-20m	<2m
Specific characters	In direct neighbourhood of forests plot F-LW.	Very high portion of dead wood.	Shrubs (0.1-2.0 m), young trees and old trees present. Strong cover of lichens indicate moist conditions.	Shrubs (0.1-2.0 m), young trees and old trees present. Strong cover of lichens indicate moist conditions.	About 300m distant from next large, close forest site. Large open areas with sparse vegetation.	About 300m distant from next large, close forest site. Large open areas with sparse vegetation.	Herbs, shrubs, young trees, dead wood and lichens lacking or with very low coverage.	In direct neighbourhood of forests plot F-SC.

Table 1. Characters of study sites (F - *Quercus ilex*-forest plots, G - garrigues). Sites are arranged from East to West. Tree, shrub and herb layer: 0 - not present, 1- present.

Table 1. Atributs de les zones d'estudi (F - *Quercus ilex*, G - garrigues). Localitats d'Est a Oest. Cobertura vegetal: 0 - absència, 1- presència.

Data analysis

We used a multivariate analysis to determine the relation between sites and the influence of environmental parameters on species. A Canonical correspondence analysis (CCA) was performed using CANOCO software. The CCA is recommended for the analysis of main patterns between environmental parameters and species or sites (Jongman *et al.*, 1995; Leps & Smilauer, 1999; McCune & Grace, 2002; McGarigal *et al.*, 2002; Palmer, 1993). We log-transformed the data for calculation and down weighted rare species to minimize the influence of species trapped only in 1-3 specimens. A permutation test with forward selection was calculated to select the most important environmental parameter and to test significance of these parameters.

Results

During the examination we recorded 17 species of Carabidae with the total number

of 1810 individuals (Table 2). One species, *Pseudomasoreus canigoulensis*, was recorded first time on the Balearic islands.

The species numbers per site varied between 2-6 in forests and 5-10 in garrigues. Despite the lower species number, the forest sites had more individuals: 323 in average compared with an average of 129.5 at the garrigue sites. The higher number of specimens in the forests is due to *Calosoma sycophanta*, the by far most abundant species (768 specimens). *C. sycophanta* is restricted to the forest sites.

The axes 1 and 2 of the multivariate analyses explain 65.6% of the variance of species data. Axis 1 splits off forest and garrigue sites (Fig. 3). Both habitat types form clearly separate groups along axis 1. The garrigue sites are divided along axis 2 whereas all forest sites are situated in the middle of that axis. That reflects a rather homogenous distribution of species in forest plots, but a gradient between species distribution of garrigues: G-EU and (G-L + G-SC) form the extreme points of the

gradient. This result does not show a geographical pattern in which G-SC (easternmost point) and G-L (westernmost point) would represent the extremes. It does also not reflect the distance between a certain garrigue and its nearest forest site, because (G-L + G-SC) are in direct

neighbourhood to a forest, but G-EO shares most species with forests and groups together with those sites in the centre of axis 2. Rather, the reason for the distribution of garrigue sites along axis 2 remains unclear. Site G-EU has the lowest coverage of vegetation and the lowest

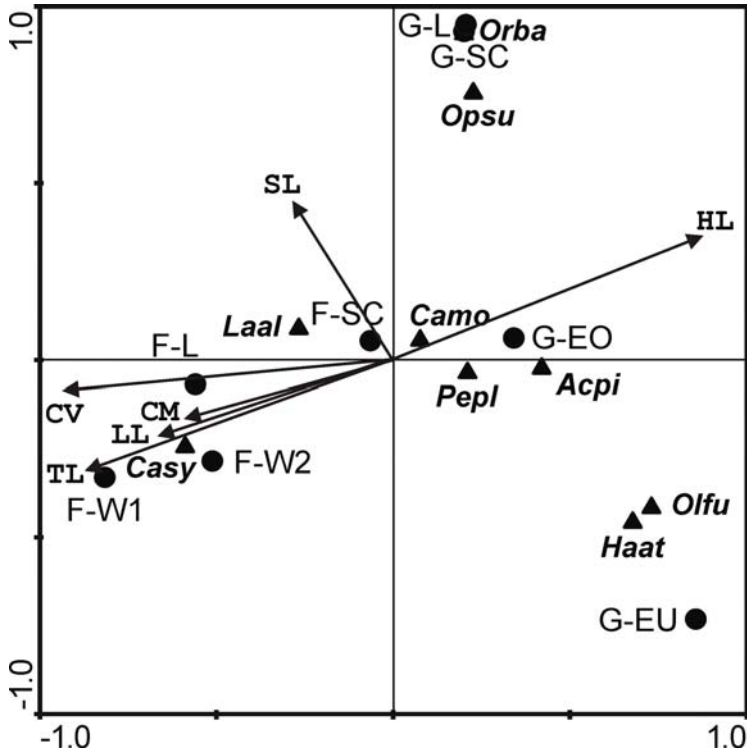


Fig. 3. Triplot of CCA showing distribution sites (circles), species (triangles) and environmental parameters (arrows) along first two axes. For site codes see Table 1; abbreviations of species see Table 2. Only species with more than 5 trapped individuals are shown. Abbreviations of environmental parameters: CM - Coverage of ground with mosses (%); CV - Total coverage with vegetation (%); HL - Herb layer; LL - Leaf litter (cm); SL - Shrub layer; TL - Tree layer. HL, SL and TL are included as presence/absence data.

Fig. 3. Triplot de CCA mostrant la distribució de les localitats (punts), les espècies (triangles) i els paràmetres ambientals (fletxes) respecte les dues primers components. Els codis de les localitats es corresponen amb la Taula 1; per als codis de les espècies consultau Taula 2. Només se representen les espècies amb 5 individus recolectats. Paràmetres ambientals: CM - Cobertura de sòl amb molses (%); CV - Cobertura total de vegetació (%); HL - Nivell herbaci; LL - fullaraca (cm); SL - nivell arbustiu; TL - nivell arbori. HL, SL i TL s'integren com a variables categòriques d'absència i presència.

	Abbr.	G-L	F-L	F-W1	F-W2	G-EO	G-EU	F-SC	G-SC	Σ
<i>Acinopus picipes</i> (Olivier, 1795)	Acpi	0	0	0	0	29	6	1	2	38
<i>Bembidion tethys</i> (Netolitzky, 1926)	-	0	0	0	0	0	2	0	2	4
<i>Calathus circumseptus</i> (Germar, 1824)	-	1	0	0	0	0	2	0	0	3
<i>Calosoma sycophanta</i> (L., 1758)	Casy	0	10	59	698	0	0	1	0	768
<i>Carabus morbillosus macilentus</i> (Lapouge, 1899)	Camo	9	1	0	29	21	5	2	1	68
<i>Harpalus attenuatus</i> (Stephens, 1828)	Haat	0	0	0	0	2	7	0	0	9
<i>Laemostenus algerinus</i> (Gory, 1833)	Laal	14	133	101	149	16	0	52	19	484
<i>Licinus punctatulus punctatulus</i> (F., 1792)	-	0	0	0	0	1	0	0	0	1
<i>Microlestes luctuosus</i> (Holdhaus, 1904)	-	0	0	0	0	0	0	0	1	1
<i>Olisthopus fuscatus</i> (Dejean, 1828)	Olfu	0	0	0	0	0	18	0	1	19
<i>Ophonus subquadratus</i> (Dejean, 1829)	Opsu	5	0	0	0	1	0	0	1	7
<i>Orthomus balearicus</i> (Piochard de la Brulerie, 1868)	Orba	0	0	0	0	0	0	0	6	6
<i>Percus plicatus</i> (Dejean, 1828)	Pepl	3	2	0	12	227	107	38	5	394
<i>Platyderus majoricus</i> (Jeanne, 1988)	-	0	0	0	2	0	0	0	0	2
<i>Pseudomasoreus canigouensis</i> (Fairmaire et Laboulbène, 1854)	-	0	1	0	1	0	0	0	0	2
<i>Trechus quadristriatus</i> (Schrank, 1781)	-	0	0	0	0	0	1	0	0	1
<i>Trechus spec.</i>	-	0	0	0	0	0	0	0	3	3
Total		32	147	160	891	297	148	94	41	1810

Table 2. Recorded Carabidae at four *Quercus ilex*- and four garrigue-sites in the Serra de Tramuntana. Column "Abbr." indicates the codes used in Fig. 3.

Table 2. Registre de caràbids a les localitats d'estudi de boscos de *Quercus ilex* i garriga a la Serra de Tramuntana. La columna "Abbr." indica els codis descrits a la Fig.3.

(lacking) inclination. The high portion of *Harpalus*, *Olisthopus* and *Trechus quadristriatus* may be correlated to these factors and distinguish the site from other studied plots. Regarding the included environmental data, the forest sites are closely related to the coverage of vegetation, mosses and leaf litter, but garrigue site G-EO to the coverage of herb

layer. The remaining garrigue sites are not related to any of the measured environmental factors.

The total coverage with vegetation (%) and the presence/absence of tree layer are the only significant parameters in the permutation test of CCA. The environmental data shown between axes 1 and 2 explain 72.1% of the variance.

Discussion

The ground beetles community changes clearly between forest and garrigue. A group of species comprising *C. sycophanta*, *P. canigoulensis* and *Platyderus majoricus* is restricted to forest sites. Ten species occur exclusively in garrigues and only four species were recorded in both habitat types. Among the latter species, only *Carabus morbillosus* is equally distributed between forests and garrigues. *Laemostenus algerinus* is a forest dwelling species which occasionally spreads to open habitats, *Percus plicatus* and *Acinopus picipes* were abundant in open habitats but occurred with a few species also in the forests. The latter result is surprising before the background that (i) garrigues of two localities are in direct neighbourhood of examined forests, (ii) many ground beetles are extremely active runners, dispersing over large distances in a few days, and (iii) the portion of forest dwelling species spreading to neighbouring garrigues is much higher in other Mediterranean regions (Arndt, unpubl. results from Greek mountains).

These results lead to following conclusions: (i) the decrease of forest area is connected with fragmentation and possible disappearing of populations of typical forest Carabidae which do not find secondary habitats in shrubland. (ii) Garrigues show a higher species number than the original forest sites but are inhabited mainly by wide spread species as *Acinopus picipes* or *Harpalus attenuatus*.

P. canigoulensis and *Platyderus majoricus* both seem to be rare forest species. *P. canigoulensis* is wide spread in the western Mediterranean area but recorded only in few numbers. Ortuño & Toribo (1996) and Taboada *et al.* (2006) found this species in forests of Spanish

mainland in low numbers as well. *P. majoricus*, an endemic species, could be endangered by extinction with decreasing forest area.

The substitution of oak forests by garrigues may generally cause a degeneration of the ground beetle community from \pm rare specialists to \pm abundant generalists.

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