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Cork-oak woodlands as key-habitats for biodiversity conservation in Mediterranean landscapes: a case study using rove and ground beetles (Coleoptera: Staphylinidae, Carabidae)

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Abstract Land-use intensification in Mediterranean agro-forest systems became a pressure on biodiversity, concerning particularly the woodland sensitive species. In 2001, the effects of a land-use gradient from old-growth cork-oak forest to a homogeneous agricultural area were assessed using rove beetles as indicators in a Mediterranean landscape. The aim was to find which species were negatively affected by land-use intensification at the landscape level and whether they benefited from cork-oak patches occurring along the land-use gradient. A total of 3,196 rove beetles from 88 *taxa* were sampled from all landscape types. Agricultural area recorded significantly higher numbers of abundance and species richness in relation to the cork-oak mosaics, i.e. the old-growth forest and the managed agro-forest landscapes (*montados*). Moreover, 70% of rove beetle indicator species common enough to be tested by IndVal displayed their highest indicator value for agriculture, showing a lower number of woodland indicators in comparison to ground beetles. Nevertheless, one rove beetle *taxon* was considered a specialist of closed woodland mosaics while no specialist ground beetle was found for that landscape typology. Some rare rove beetle species were also important in typifying diversity patterns of old-growth cork-oak forests. Hence, future management in Mediterranean landscapes should take into account not only indicator species common enough to be tested by IndVal, but also rare and endemic species. Considering the added value of cork-oak woodland cover for sensitive rove and ground beetle diversity, the strengthening of cork-oak woodland connectivity seems to be a crucial management that is required in agricultural Mediterranean landscapes.

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Introduction

Traditional management practices in Mediterranean landscapes dominated by cork-oak
woodland areas are known to provide complex and dynamic agro-forest mosaics (Verdú
et al. 2000; Taboada et al. 2006). This low intensity of land-use disturbance is able to
sustain high levels of biodiversity due to species turnover between agriculture and
woodland habitats (e.g. Romero-Alcaraz and Ávila 2000; Woodcock et al. 2005). How-
ever, land-use intensification occurring in the last decades led to the loss of natural and
semi-natural habitats (Rainio and Niemelä 2003), resulting in a pressure on woodland
specialist species (Niemelä et al. 1993; Magura et al. 2000). These usually occupy narrow
niches in old and unfragmented habitats, having few suitable habitats for dispersion and so
being more sensitive to the effects of habitat disturbance than generalists (Halme and
Niemelä 1993; Niemelä and Baur 1998; Petit and Usher 1998; Kotze and O'Hara 2003;
Buddle et al. 2006). Hence the implementation of such accurate ecological indicators is
required for conservation and management of dynamic agro-forest ecosystems. In this
context, the project "Biodiversity Assessment Tools" (BIOASSESS: http://www.nbu.ac.
uk/bioassess/) targeted the development of a set of ecological indicators able to monitor
biodiversity changes in human-disturbed landscapes according to a land-use gradient
(Sousa et al. 2006). One of the *taxa* studied in the BIOASSESS was ground beetles (e.g.
Martins da Silva et al. 2008). In theory, rove beetles are as well suitable bio-indicators in
agro-ecosystems since they are also dominant (in some cases more than ground beetles) in
terms of abundance, diversity and predatory activity in those landscapes (Shah et al. 2003;
Hofmann and Mason 2006). Rove beetles also occur in a wide range of habitats and are
strongly influenced by the structure of cultural landscapes and different intensities of land-
use management (Bohac 1999; Markgraf and Basedow 2002). However, rove beetles have
not been so frequently used as bio-indicators in comparison to ground beetles, largely due
to taxonomic constrain and lack of species ecology information (Bohac 1999; Andersen
and Eltun 2000). These drawbacks are more prominent in the Mediterranean region where
rove beetles are particularly species-rich and poorly known, with a substantial number of
endemics, namely from the Iberian Peninsula and specifically from Portugal (e.g. Drug-
mand and Outerelo 1997; Martins da Silva et al. 2006). In this study, we used rove beetles
as indicators of land-use intensification, comparing its results with those previously
obtained for ground beetles (Martins da Silva et al. 2008). The aim was to assess the effects
of land-use intensification on beetle diversity patterns at the landscape scale, identifying
which species benefited from woodland habitats along the land-use gradient. Such species
should be a key monitoring tool in future conservation and management strategies.

Materials and methods

Site description and beetle sampling

The field work was conducted in 2001 in typical Mediterranean cork-oak areas (*Quercus
suber*) under different types of management. The sampling sites were located in the
consolidated alluvial plain of the river Tagus, 20 km east of Lisbon, Portugal (ca 42°50′N

51°50′E). Land-use gradient ranged from unmanaged old-growth cork-oak woodland to an intensively managed agricultural field.

The old-growth cork-oak woodland was located in a buffer zone for military purposes. This situation caused a low level of management in this site over the last 50 years, resulting in a closed woodland dominated by cork-oak trees, despite the presence of maritime pine (*Pinus pinaster*) and umbrella pine (*Pinus pinea*).

The agricultural system was, since 1988, a homogeneous and permanently irrigated alfalfa field (*Medicago sativa*). Alfalfa, used as fodder, was sown for the first time in April 2001, mowing occurred four to five times each year (April–August), in the expected 7 years of hay exploitation. Three mineral fertilisations (N, P, K – 8, 24, 24, respectively) of 300 Kg/ha were made each year.

The intermediate land-use intensification levels comprised three managed agro-forest mosaics (*montados*). They were privately owned by an agro-forestry company ("Companhia das Lezírias") for multiple uses, resulting in different landscape typologies (Sousa et al. 2004): a closed *montado*, where pruning has been done over 2 years before sampling; an open *montado*, with patches of natural grassland subjected to occasional grazing; and a *montado*, dominated by pastures with higher management level of extensive grazing. In each landscape type, a grid of 16 sampling points was established with four pitfall traps per point; the sampling protocol was the same used for ground beetles (see details in Martins da Silva et al. 2008). Table 1 summarises the habitat heterogeneity occurring within each studied landscape type (details in Sousa et al. 2004). Identification of rove beetle species was based on an extensive literature, but mainly on the works of Freude et al. (1964), Coiffait (1972, 1974, 1978, 1982, 1984) and Outerelo and Gamarra (1985). Due to the lack of proper identification keys, the identification of several Aleocharinae species was not achievable.

Table 1 Habitat heterogeneity and major interventions on each landscape (numbers indicate number of sampling points at each habitat/land-use type)

| Habitat types and interventions	Cork-oak mosaics				Agriculture
	Old-growth	Managed *montados*			
		Closed	Open	Pastures	
Closed woodland	8	11	4	4	
Open woods	3	5	9	6	
Shrub area	3			1	
Grassland	2				
Pasture			3	5	
Agriculture					16
Understorey	With 10–15 years old	Removal every 6–8 years	With 8 years old	Strongly reduced	
Interventions	None	Pruning	Occasional grazing	Extensive grazing	Intensively irrigated field
Management level	None	Low	Medium	Medium	High

Old-growth: unmanaged cork-oak woodland; closed: *montado* dominated by closed woodlands; open: dominated by open woodlands; pastures: *montado* with more proportion of pasture areas in relation to the other mosaics; agriculture: managed monoculture of alfalfa

Data analysis

Rove beetles activity densities and number of species found at each landscape type were compared by an ANOVA, followed by a Tukey test. If assumptions of homogeneity of variances and normality (verified previously using Bartlett and Kolmogorov–Smirnov tests, respectively) were not met, data were log transformed. All the above statistical calculations were made using the SigmaStat software (SPSS 13.0).

Regarding rove beetle richness, species accumulation curves were calculated in "Species Diversity and Richness" 3.0 software as the mean score after 100 randomisations, in order to check the species inventory efficiency and completeness in the studied sampling sites (e.g. Moreno and Halffter 2000; Hortal et al. 2006). Both rove and ground beetles' diversity patterns, along the land-use gradient, were analysed by multivariate techniques. Firstly, a detrended correspondence analysis (DCA) based on beetle species composition was performed to identify the gradient length. Subsequently, a canonical correspondence analysis (CCA) was done using log transformed data and based on the "sampling points versus *taxa*" data matrices. Statistical significance of the canonical axes was evaluated by a Monte Carlo permutation test. CCAs were performed in CANOCO 4.0 software.

Indicator species of each landscape type were identified for both beetle families using the Indicator Value (IndVal) method (Dufrêne and Legendre 1997). A previous step of this analysis was to obtain an a priori site typology using a hierarchical clustering method (Ward method) based on the Bray–Curtis similarity distances. Hence, the five studied landscape types were grouped according to the structure of the vegetation cover which was formed due to different land-use intensifications (Fig. 1, but see also Table 1). The first level of the classification grouped all sites. The second level separated "agriculture" from all landscapes dominated by cork-oak patches ("cork-oak mosaics"). The third level distinguished landscapes dominated by closed woodlands ("old-growth" and "closed *montado*") from landscapes dominated by open areas ("open *montado*" and "pastures") and the fourth separated all these landscape typologies (Fig. 1). The second step of this analysis was to identify the indicator species of each group of the site typology. According to Dufrêne and Legendre (1997), where species had the highest IndVal value they were used to indicate that group. Indicator values of 25 were considered the minimum level for the index (Dufrêne and Legendre 1997) as well as species with indicator values of at least 80 were regarded as specialists in particular landscape types (Pohl et al. 2007).
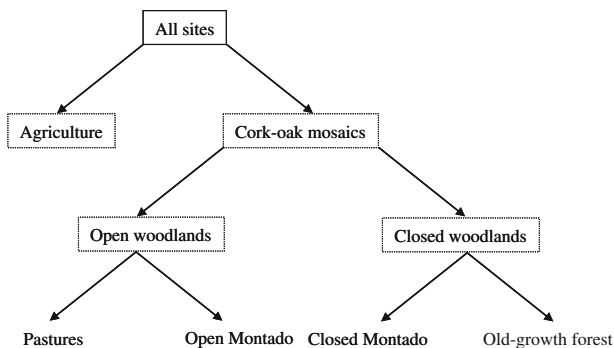
Fig. 1 Site a priori classification using an hierarchical clustering method based on the Bray–Curtis similarity distances. The landscape typology was based on the proportion of the five main habitat/land-use types

A randomisation procedure among site groups was performed, using 250 permutations, to test the significance of IndVal (Dufrêne and Legendre 1997).

Results

### Abundance and species richness

Rove beetles comprised about 21.7% of all sampled beetles (32.8% were ground beetles). A total of 3,196 rove beetle specimens belonging to 88 *taxa* were recorded in all landscape types. Mean abundance and species richness were significantly higher in the agricultural field (total $S = 61$) than in landscapes of cork-oak mosaics (total richness was lower in the closed *montado*: $S = 24$) (Fig. 2a, b). Regarding these abundance and richness, differences between the forested and open areas within each landscape type were not significant (Fig. 2a, b). Species accumulation curves performed for all study sites revealed that sampling effort did not achieve the rove beetle species inventory completeness, as the asymptote (the curve "plateauing") was not obvious even for the richest agricultural landscape (Fig. 3).

The dominant *taxa* were *Atheta* sp. (19.2%), *Xantholinus longiventris* Heer (11.9%), *Aleochara bipustulata* (Linnaeus; 8.95%), *Ocypus aethiops* (Waltl; 8.51%), *Sepedophilus*

Fig. 2 Rove beetle abundance (**a**) and richness (**b**) along the land-use intensification gradient (mean values and SE). Old, old-growth; Clo, closed *montado*; Ope, open *montado*; Pas, pastures; Agr, agriculture (*shaded bars* forested areas and *white bars* open areas). The *asterisk* indicates different groups after Tukey test ($P < 0.05$)
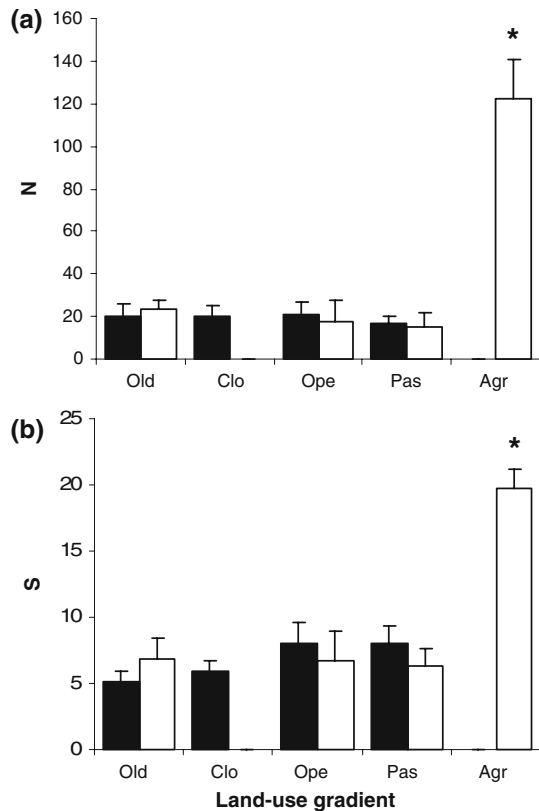
Fig. 3 Randomised accumulation curves for the rove beetles' species richness recorded in the different landscape types
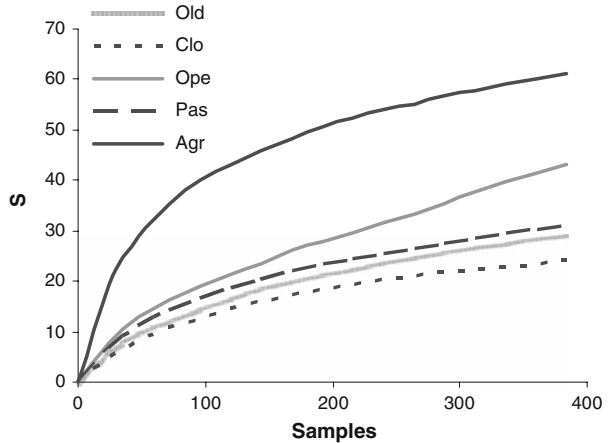

sp. (7.85%) and *Quedius cobosi* Coiffait (5.82%) (Table 2). Thirteen species were sub-dominant (1–5%) and all others rare (29 species were singletons). The overall taxonomic composition of dominant and subdominant species was strongly influenced by the agriculture site (Table 2). In fact, although *X. longiventris*, *A. bipustulata* and *Philonthus cognatus* Stephens were dominant (as well as *Megalinus glabratus* Gravenhorst was subdominant) in the agriculture, they were rare or even did not occur in the other landscapes. Inversely, *O. aethiops* was strongly dominant in old-growth and closed *montados* and also dominant in more open mosaics, but less common in agriculture. Moreover, *Sepedophilus*

Table 2 Rank (*R*) and percentage (%) of dominant (more than 5% of relative abundance) and sub-dominant species (1–5%)

	Old		Clo		Ope		Pas		Agr		Total	
	R	%	R	%	R	%	R	%	R	%	R	%
Atheta sp.	6	3.2	9	1.6	3	11	8	3.5	1	28	1	19
Xantholinus longiventris Heer	*				**		6	4.7	2	19	2	12
Aleochara bipustulata (Linnaeus)					*				3	15	3	8.9
Ocypus aethiops (Waltl)	1	50	2	21	6	5.6	5	5	25	0.2	4	8.5
Sepedophilus sp.	4	6.7	1	48	4	9.7	2	14				7.9
Quedius cobosi Coiffait	7	2	11	1.2	1	19	4	7.4	5	4.9	6	5.8
Atheta longicornis (Gravenhorst)	2	11	5	2.8	5	8.6	11	2.3	7	3.8	7	4.8
Ocypus olens Müller	*		3	6.8	2	15	1	22	10	1.3	8	4.8
Philonthus cognatus Stephens									4	5	9	3
Megalinus glabratus Gravenhorst					*		8	3.5	6	3.9	10	2.8
Quedius tristis (Gravenhorst)	9	1.5	8	1.9	7	5.3	7	4.3	9	1.5	11	2.1
Tachyporus nitidulus (Fabricius)	3	8.5			10	2.2	7	4.3	20	0.5	13	1.8
Quedius semiaeneus (Stephens)	10	1.2	14	0.9	*		9	3.1	8	1.8	14	1.6
Xantholinus translucidus Scriba	10	1.2	4	5	12	0.9	3	9.7			15	1.5
Quedius latinus Gridelli	**		*		8	5			12	1.1	16	1.3
Quedius nigriceps Kraatz	5	4.4	7	1.9	12	0.9			22	0.4	17	1

Shaded numbers indicate the three more abundant species in each landscape type
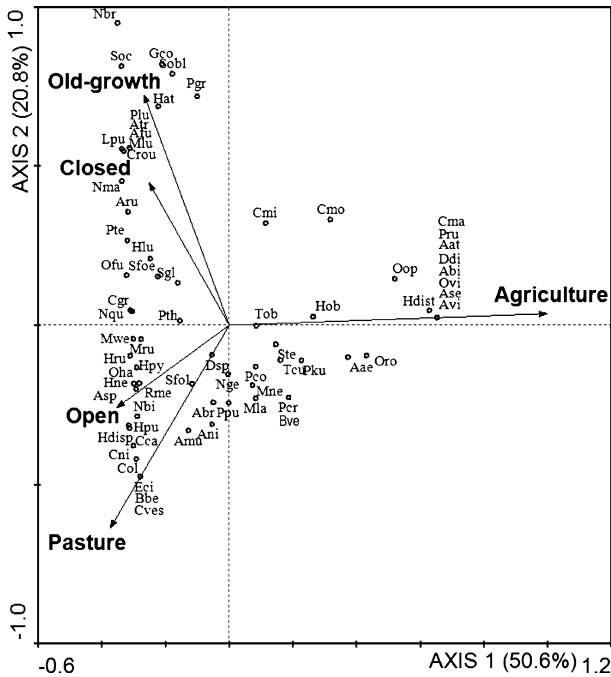
*Singletons; **doubletons
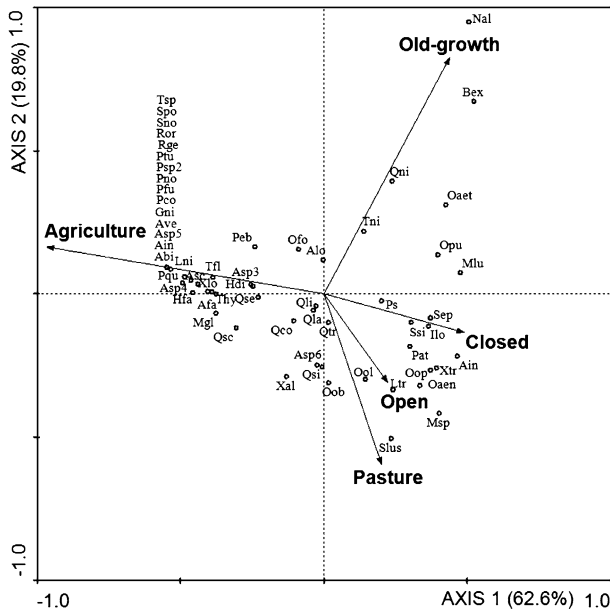
Fig. 4 CCA based on rove beetle community composition of the different landscape types. Significance of canonical axes: axis 1, $F = 12.5$ ($P < 0.01$); other axes, $F = 5.561$ ($P < 0.01$)

sp. was the most dominant in closed *montados*, as well as *Q. cobosi* and *Ocypus olens* Müller were the most common species in mosaics dominated by open woodlands and pastures, respectively.

From the 12 endemic species found along the landscape types, only one was dominant (*Q. cobosi*), one was sub-dominant (*Xantholinus translucidus* Scriba: 1.5%) and the other ten were rare. Of these, two were exclusives from old-growth forest (*Nazeris algarvensis* Coiffait, *Nazeris ibericus* Koch), two were exclusives from open *montado* (*Leptobium doderoi* Gridelli, *Parameropaederus lusitanicus* (Aubé)) and two were exclusives from agriculture (*Achenium hartungi* Wollaston, *Scopaeus portai lusitanicus* Luze).

Regarding beetle diversity patterns, a DCA revealed an unimodal relationship to the land-use gradient (axis 1: eigenvalue = 0.55, gradient length = 3.98 SD). The same analysis was made for ground beetles which also showed an unimodal relationship to the gradient (axis 1: eigenvalue = 0.63, gradient length = 3.77 SD). Accordingly, a CCA was performed for both families and clearly separated agriculture area from the cork-oak mosaics along the first canonical axis (explaining 62.6 and 50.6% of the variability for rove and ground beetles, respectively; Figs. 4, 5). The second canonical axis of the CCA (explaining 19.8 and 20.8% of the variability, respectively) discriminated beetle species composition among the cork-oak mosaics. A clear differentiation between landscapes dominated by closed woodlands (old-growth and closed *montado*, on the positive side) from the more open landscapes (open *montado* and mosaics dominated by pastures, on the negative side) occurred in the case of ground beetles (Fig. 5). Concerning rove beetles, old-growth (on the positive side) detached from the other cork-oak mosaics (on the negative side), mainly due to the occurrence of some rare species, such as *Bolitobius exoletus* Erichson (coded "Bex" in Fig. 4) and the endemics *Medon lusitanicum* Coiffait ("Mlu") and *N. algarvensis* Coiffait ("Nal").

Fig. 5 CCA based on ground beetle community composition of the different landscape types. Significance of canonical axes: axis 1, $F = 12.3$ ($P < 0.01$); other axes, $F = 7.25$ ($P < 0.01$)

Indicators of land-use

Regarding the indicator value analysis, 32 rove beetle species as well as 24 species from the ground beetle data of Martins da Silva et al. (2008) were common enough to be tested, i.e. recorded an IndVal value equal or superior to 25 (Figs. 6, 7). All but two rove beetle species, as well as two ground beetles species, exhibited significant indicator value ($P < 0.05$) for at least one, or combination of some, landscape type(s). Concerning rove beetles, 22 species (more than 70%) displayed their highest indicator value for agriculture (Fig. 8). *Aleochara bipustulata* (99.7) and *X. longiventris* (95.8) recorded the highest indicator values and thereby were considered specialists of this site (Fig. 6). Only 29% of *taxa*, namely *Sepedophilus* sp., *O. aethiops*, *X. translucidus* and *O. olens*, recorded higher indicator values for the cork-oak mosaics. Nevertheless, *Sepedophilus* sp. (81) was considered a specialist of closed *montados*. *Ocypus aethiops* also fitted as a fairly stenotopic species of forest landscapes although its higher indicator value (76.2 in the old-growth mosaic) did not reach the 80. This species was replaced for *O. olens* in landscape types dominated by open areas (open *montado* and pastures), where *O. olens*, a well as *Q. cobosi*, were more common (Fig. 6). Concerning ground beetles, nine species (40%) recorded the highest indicator value for agriculture (Fig. 8). Three species, i.e. *Campalita maderae* (Fabricius), *Pseudophonus rufipes* (De Geer) and *Harpalus distinguendus* (Duftschmid), were considered specialists of agricultural areas. Furthermore, *C. maderae* and *P. rufipes* recorded the maximum (100) indicator value for this area. More than 60% of ground beetle species, but particularly *Rhabdotocarabus melancholicus* Breuning, *Hadrocarabus lusitanicus* (Fabricius), *Steropus globosus* (Quensel) and *Calathus granatensis* Vuillefroy,
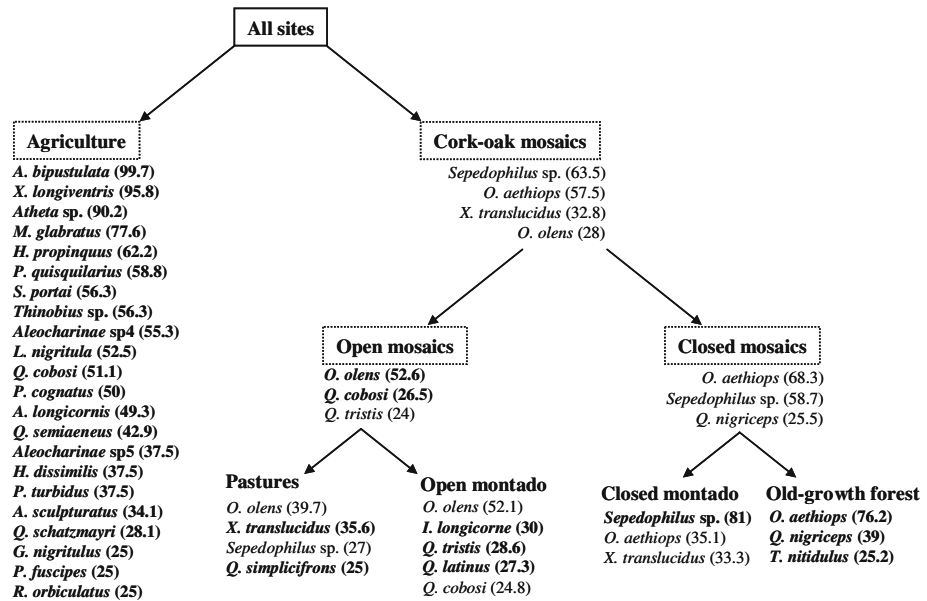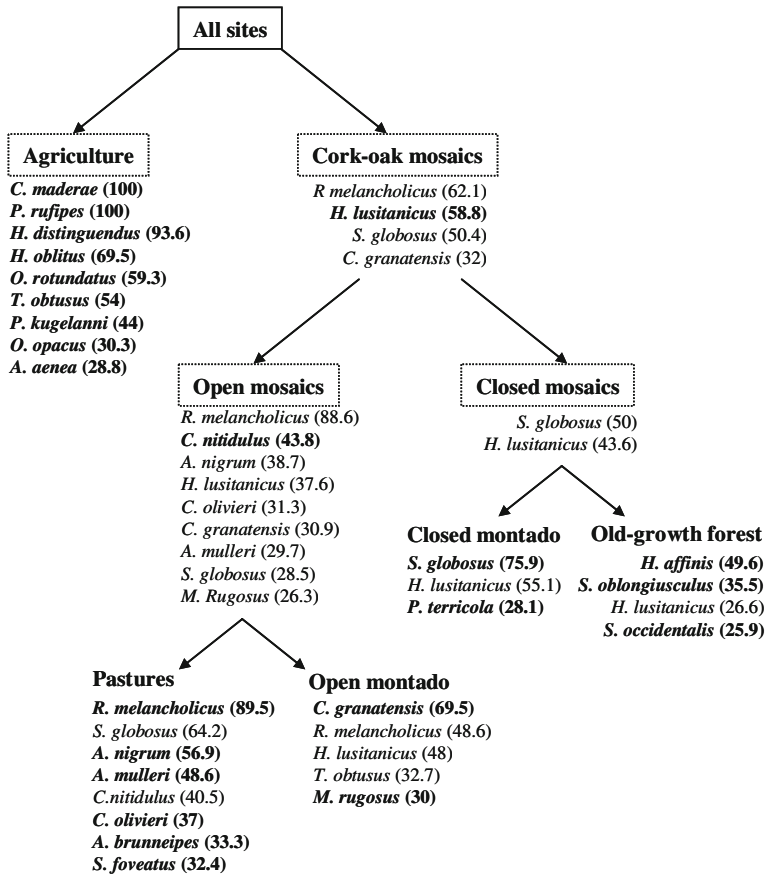
Fig. 6 Rove beetle indicator species (indicator values sensu Dufrêne and Legendre 1997) superimposed on the site cluster obtained from a clustering method based on the Bray–Curtis similarity distances. All indicator species with significant ($P < 0.05$) indicator values are included (indicator value is given in *parenthesis*). The maximum indicator value of each species is indicated in *bold*

recorded higher indicator values for the cork-oak mosaics (Fig. 7). From these, 39% of species were indicators of landscapes dominated by open areas. *Rhabdotocarabus melancholicus* was deemed to be specialist of *montados* dominated by pastures (IndVal = 89.5), while *C. granatensis* recorded the higher indicator value for *montados* dominated by open woodlands. A lower number of species (about 22%), particularly *H. lusitanicus* and *S. globosus*, were more associated to closed mosaics. Moreover, *H. lusitanicus* and *S. globosus* revealed a more or less eurytopic distribution within overall mosaic landscapes, despite the highest indicator value of *S. globosus* (75.9) was attained for the closed *montado* (Fig. 7).

Discussion

General response to land-use intensification

In line with the results from ground beetles (Martins da Silva et al. 2008), the highest species richness and abundance of rove beetles were recorded in the extremely homogeneous and frequently disturbed area: the agricultural landscape. Considerable evidence from other studies, concerning rove and ground beetles, is also consistent with this result (e.g. Buse and Good 1993; Magura et al. 2001; Brose 2003; Vanbergen et al. 2005). In fact, the positive response of both beetle families to land-use intensification was expected considering that generalists and open-habitat beetles are usually dominant in terms of abundance and richness in the species assemblages of pitfall samples (Kromp 1999; Heliölä et al. 2001; Larsen et al. 2003). It seems hence reasonable to presume that a major

All sites

Agriculture

C. maderae **(100)**
P. rufipes **(100)**
H. distinguendus **(93.6)**
H. oblitus **(69.5)**
O. rotundatus **(59.3)**
T. obtusus **(54)**
P. kugelanni **(44)**
O. opacus **(30.3)**
A. aenea **(28.8)**

Cork-oak mosaics

R melancholicus (62.1)
H. lusitanicus **(58.8)**
S. globosus (50.4)
C. granatensis (32)

Open mosaics

R. melancholicus (88.6)
C. nitidulus **(43.8)**
A. nigrum (38.7)
H. lusitanicus (37.6)
C. olivieri (31.3)
C. granatensis (30.9)
A. mulleri (29.7)
S. globosus (28.5)
M. Rugosus (26.3)

Closed mosaics

S. globosus (50)
H. lusitanicus (43.6)

Closed montado

S. globosus **(75.9)**
H. lusitanicus **(55.1)**
P. terricola **(28.1)**

Old-growth forest

H. affinis **(49.6)**
S. oblongiusculus **(35.5)**
H. lusitanicus (26.6)
S. occidentalis **(25.9)**

Pastures

R. melancholicus **(89.5)**
S. globosus (64.2)
A. nigrum **(56.9)**
A. mulleri **(48.6)**
C.nitidulus (40.5)
C. olivieri **(37)**
A. brunneipes **(33.3)**
S. foveatus **(32.4)**

Open montado

C. granatensis **(69.5)**
R. melancholicus (48.6)
H. lusitanicus (48)
T. obtusus (32.7)
M. rugosus **(30)**

Fig. 7 Ground beetle indicator species (indicator values sensu Dufrêne and Legendre 1997) superimposed on the site cluster obtained from a clustering method based on the Bray–Curtis similarity distances. All indicator species with significant ($P < 0.05$) indicator values are included (indicator value is given in *parenthesis*). The maximum indicator value of each species is indicated in *bold*

Fig. 8 Relative number of rove and ground beetles' indicator species found for each landscape type along the land-use gradient
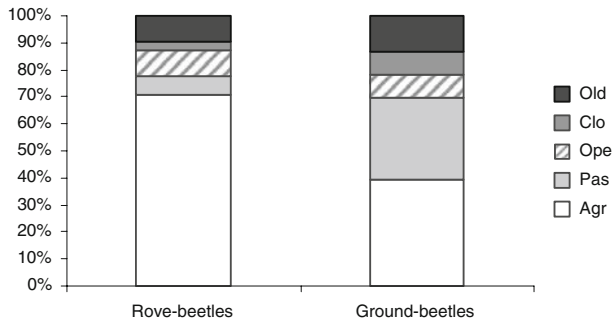
part of these soil dwelling beetles have found in the monoculture a large amount of suitable habitat (e.g. moisture conditions of the permanently irrigated alfalfa field) and resource availability sustaining their higher activity. Concerning beetle diversity patterns agriculture

communities clearly differed from all other landscape types, showing the importance of agriculture areas for species turnover within the dynamic forest–agriculture fragmented landscapes (e.g. Buse and Good 1993). Moreover, according to the indicator value analysis (Dufrêne and Legendre 1997), a considerable number of beetle species were found as specialists of agriculture areas. These results highlight the key role of some epigaeic predators (e.g. *C. maderae*) as well as parasitoids (e.g. *A. bipustulata*) as pest controllers in typical Mediterranean agro-ecosystems.

Woodland beetles as indicators

Ground beetles showed a considerable higher number of indicator species associated to the cork-oak mosaics in comparison with rove beetles (see Fig. 8). Nevertheless, most of ground beetle species were apparently less negatively affected by the land-use intensification gradient within the mosaic landscapes. Most species were indicators of landscapes dominated by open woodlands or pasture habitats and one was considered a specialist of this latter landscape typology. A lesser relative number of indicator species were more associated to mosaics dominated by closed woodlands. Moreover, although some ground beetle species had already been designated as old-growth specialists in previous studies (e.g. Spence et al. 1996; Magura et al. 2001; Paquin 2008), no old-growth woodland specialists (according to Pohl et al. 2007) were found here. Concerning rove beetles, despite the relative lower number of indicators found for the cork-oak mosaics, one *taxon* (*Sepedophilus* sp.) was considered a specialist for landscapes dominated by closed woodlands. In fact, most species of the genus *Sepedophilus* (subfamily Tachyporinae) are deemed to be primarily associated with fungous in decaying wood and hence they are largely found in bark or litter of ancient broad-leaved woodlands (Alexander 2002). Moreover, other rove beetle species (*O. aethiops*) was "almost" a specialist for old-growth woodlands. The application of the IndVal at the landscape level revealed a higher fidelity of some rove beetle species to mosaics with higher cover of cork-oak woodlands. Such species could therefore be more threatened by the effects of land-use intensification in Mediterranean agro-forest landscapes. Regarding the CCA analysis, Carabidae communities were able to unambiguously discriminate diversity patterns of closed-woodland mosaics from more open landscapes, revealing a stronger connection with the a priori landscape typology than rove beetles. On the other hand, Staphylinidae communities were able to discriminate the old-growth woodland from the agro-forest managed mosaics. Some species that were not common enough to be tested in the indicator value analysis, one of them is endemic (*N. algarvensis*), supported the distinctive pattern of this landscape type in relation to the others. The association of some rove beetle species to particular mature forests was found in other studies, indicating their higher response to a finer scale of habitat variation in relation to ground beetles (Pohl et al. 2007).

Having said this, it is not negligible to observe that sampling effort of this study, based on pitfall traps like most rove beetle studies (e.g. Shah et al. 2003; Lawes et al. 2005; Hofmann and Mason 2006; Pohl et al. 2007), was not sufficient to completely assess species richness, particularly in the forested sites where the habitat vertical structure is much more complex than in cultivated areas. Therefore, a substantial number of opportunistic staphylinid predators and fungivorous species could probably be widely dispersed all over the forest habitat besides the soil. For instance, Duelli and Obrist (1998) found that window flight interception traps efficiently collect rove beetles with good flight ability. Particularly, the use of ground based and trunk-window traps have adequately recorded saproxylic rove beetles such as *Lordithon* and *Sepedophilus* spp. (e.g. Kaila et al. 1997;

Sverdrup-Thygeson 2001; Müller et al. 2008). Hence, considerable more rove beetle species and possibly more forest specialists could be found using complementary sampling methods.

Conservation relevance and conclusions

Despite the general positive response of these epigaeic beetles to the land-use intensification, conservation prioritisation should not be given only on the basis of species richness, but rather focus on those potentially more susceptible to habitat loss and fragmentation (Gutiérrez et al. 2004). This is the case of the woodland sensitive beetles (e.g. Halme and Niemelä 1993; Sroka and Finch 2006; Spitzer et al. 2008) particularly in Mediterranean agro-forest landscapes. Although forest indicator species (according to Dufrêne and Legendre 1997) were scarcely found in this study, some rare and endemic rove beetle species characterised old-growth cork-oak woodlands, highlighting their importance as key-habitats (sensu Tews et al. 2004) for biodiversity conservation. In fact, regardless the suitability of the "indicator value method" for the identification of characteristic species of certain habitats, the use of rare species (and particularly endemics) has been indicated as an essential tool for typifying areas of high conservation potential (e.g. Kerr 1997; Anderson and Ashe 2000; Borges et al. 2000; Pykälä et al. 2005; Bates et al. 2007). Considering the added value of *Q. suber* cover for the protection of sensitive rove and ground beetles, it would be necessary to strengthen the connectivity of cork-oak patches in agricultural Mediterranean landscapes. This management practice could compensate for isolation between local populations, enhancing dispersal and long-term survival of rove and ground beetles' metapopulations at the landscape level (Petit and Usher 1998; Magura et al. 2000, 2001). Species turnover between agriculture crops and woodland field boundaries would also improve the pest-control service provided by most rove and ground beetles (e.g. Woodcock et al. 2005), enhancing the sustainable use of Mediterranean agro-forestry systems. In fact, besides conservation purposes, other motivations for biodiversity assessment such as pest control, but also ecological resilience and ecosystem functioning (e.g. Bengtsson 1998; Duelli and Obrist 2003) could benefit from the integration of rove beetles (along with ground beetles) in the "indicator basket" (sensu Duelli and Obrist 2003; Lawes et al. 2005) of sampling protocols, considering their extensive richness and wide range of size groups, trophic habits, habitat width and life forms (e.g. Bohac 1999).

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