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► **To cite this version:**

S M Santos, I T Do Rosário, M L Mathias. MICROHABITAT PREFERENCE OF THE CABRERA VOLE IN A MEDITERRANEAN CORK OAK WOODLAND OF SOUTHERN PORTUGAL. *Vie et Milieu / Life & Environment*, 2005, pp.53-59. hal-03219010

**HAL Id: hal-03219010**

**<https://hal.sorbonne-universite.fr/hal-03219010>**

Submitted on 6 May 2021

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## MICROHABITAT PREFERENCE OF THE CABRERA VOLE IN A MEDITERRANEAN CORK OAK WOODLAND OF SOUTHERN PORTUGAL

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MICROHABITAT  
MICROTUS CABRERAE  
LOGISTIC REGRESSION  
CORK OAK WOODLAND  
MEDITERRANEAN  
CABRERA VOLE

**ABSTRACT.** – In this study, data on microhabitat preference of the Cabrera vole (*Microtus cabreræ*) was obtained in a cork oak woodland of southern Portugal over an area of 221 ha. A total of 35 and 30 colonies were surveyed, respectively, in the dry and wet seasons (April to June and October to December, respectively) and 22 variables defining microhabitat structure and composition were monitored within a 10 m-radius circle around each colony. Two logistic regression models were separately computed for the dry and wet seasons, aiming to identify the more relevant variables influencing the presence of voles. Models were statistically robust, revealing good predictive ability (dry season: 94.1% of correct classifications and AUC=0.987; wet season: 82.4% of correct classification and AUC=0.869). Results suggest that open areas with high herbaceous cover were the most important microhabitat factors determining the occurrence of voles across the year. Results also showed that colonies distribution and spacing greatly varied throughout the year which may be highly relevant in the species conservation planning.

MICROHABITAT  
MICROTUS CABRERAE  
MODÈLES DE RÉGRESSION LOGISTIQUE  
FORÊT DE CHÊNES-LIÈGES  
BASSIN MÉDITERRANÉEN  
CAMPANOL

**RÉSUMÉ.** – Dans ce travail, nous déterminons les variables les plus importantes qui influencent la distribution du Campagnol de Cabrera (*Microtus cabreræ*), le Rongeur le plus menacé au Portugal. Les données ont été obtenues dans une chênaie de Chêne-liège au sud du Portugal, sur 221 ha. Un total de 35 et 30 colonies ont été enregistrées, correspondant aux saisons sèche (avril - juin) et humide (octobre - décembre), et 22 variables mesurées dans un cercle de 10 m de rayon qui entoure chaque colonie, ont permis de définir la structure et la composition du microhabitat. Deux modèles de régression logistique ont été construits pour les deux saisons. Les modèles obtenus sont statistiquement robustes et présentent une bonne capacité prédictive (saison sèche : 94,1% de classification correcte et AUC = 0,987 ; saison humide : 82,4 % de classification correcte et AUC = 0,869). Nos résultats démontrent l'importance des surfaces ouvertes (clairières) avec de grandes couvertures de plantes herbacées comme des facteurs déterminants de la présence du Campagnol de Cabrera. Ils montrent aussi que la distribution et l'espacement des colonies peut considérablement changer pendant l'année, ce qui doit être pris en compte en vue de la conservation de l'espèce.

### INTRODUCTION

The Cabrera vole (*Microtus cabreræ* Thomas, 1906) is an endemic and threatened rodent in the Iberian Peninsula, listed in the annex III of the Bern Convention (Cabral *et al.* 1990, Blanco & González 1992) and in the annex II of the Habitat Directive (92/43/EEC). This species occurs only in areas of Mediterranean climate (e.g. San Miguel 1992) and has developed physiological adaptations to cope with high temperatures and the water deficit during the summer months (Blondel & Aronson 1999, Mathias *et al.* 2003).

Locally, animals are grouped in colonies, frequently of reduced dimensions (*ca.* 300 m<sup>2</sup>) with densities varying from one to five animals per 500 m<sup>2</sup>, depending on the time of the year (Fernández-Salvador 1998). These colonies show a patchy distribution over brush woods near small streams and in areas of high grasses or herbaceous vegetation, frequently associated with oaklands (Soriguer & Amat 1988, San Miguel 1992, Fernández-Salvador 1998, Mathias 1999, Fernández-Salvador *et al.* 2001). Yet, albeit habitat destruction has been pointed out as the major threat for this species survival (Cabral *et al.* 1990, San Miguel 1992), reduced information is available on the precise

microhabitat requirements which regulate the presence of voles, such as quantitative data on habitat characteristics that make potentially good habitat inappropriate for Cabrera voles (Landete-Castillejos *et al.* 2000).

The cork oak (*Quercus suber*) is one of the dominant tree species in areas under 500 m a.s.l. of the southwestern Thermo-Mediterranean region (Rivas-Martínez 1987, Blondel & Aronson 1999). Although with a narrow distribution in Spain, cork oak woodland is the most widespread evergreen oakland in Portugal (Natividade 1990), covering about one third of the area enclosing all known *M. cabrae* colonies (San Miguel 1992, Fernández-Salvador 1998, Mathias 1999).

This study, which is part of a larger one towards a conservation strategy for the Cabrera vole, aims at identifying microhabitat descriptors associated with the presence of voles in a Mediterranean cork oak woodland in southern Portugal. Thus, a set of variables reflecting characteristics of the microhabitat, were monitored in two different seasons and analysed using logistic regression analysis.

## METHODS

**Study area:** The present study was carried out in southern Portugal, over an area of 221 ha (Herdade da Ribeira Abaixo, Grândola, 38°08'N, 8°33'W), in two different periods: a dry season and a wet season (see below). The study area is included in the Iberian Thermo-Mediterranean belt (Rivas-Martínez & Arregui 1999), characterized by dry hot summers and mild wet winters (Blondel & Aronson 1999). Mean air temperatures were 17.4 °C (minimum of 4.5°C and maximum of 36°C) for the dry season and 15.1°C (minimum of 0°C and maximum of 29°C) for the wet season. Total rainfall was 117 mm for the dry season and 368 mm for the wet period (data from Professional School of Agriculture and Rural Development of Grândola, 8 km from the study area). The area and surroundings are included in the Grândola mountain system, averaging in altitude 325 m a.s.l., which is part of one of the most important cork oak woodland formations (*Quercus suber*) in Portugal (Natividade 1990, Santos-Reis & Correia 1999). Scrub understorey is dominated mainly by *Cistus salviifolius*, *C. ladanifer*, *C. populifolius*, *Lavandula luisieri*, *Arbutus unedo* and *Erica arborea* (Correia & Nisa 1999).

**Data collection:** Colonie survey was carried out from April to June 2002 (dry season) and from October to December 2002 (wet season). The samples consisted, respectively, of 35 and 33 presence and absence circles for the dry season and 30 and 39 presence and absence circles for the wet season. Average area occupied by presence signs varied between 250 m<sup>2</sup> (0,25 – 800 m<sup>2</sup>) in the dry season and 166 m<sup>2</sup> (1 – 1000 m<sup>2</sup>) in the wet season.

Several signs of presence, such as tunnels in the vegetation, feces, latrines and grass clipping in the tunnels, allowed the identification of the colonies but the “pres-

ence of voles” was only assigned if feces were found. A regular procedure was followed for presence sampling aiming to cover all the study area. Sampling began at one extreme and once a presence was registered, a 100 m-radius buffer was defined before starting a new survey. A 10 m-radius circle was defined around each colony, within which, nine variables defining microhabitat structure and composition were monitored through visual estimation (Table I). The variable HETERO describes the vegetation spatial structure inside the sampling circle: 1-homogeneous, when circle is only covered by herbs or shrubs; 2- two distinct patches, one of herbaceous vegetation and another of shrubs; 3- a corridor like structure, when there is one patch of herbs surrounded by shrubs; or 4-dispersed patches, when there are several patches of shrubs inside a matrix of herbs, or *vice versa*.

In addition, two orthogonal transects were defined within each circle and, at every meter, vegetation categories and heights were also recorded using a pointed pin-meter (“Line intercept” method, Hayes *et al.* 1981). This procedure resulted in 42 point vegetation records per circle and allowed the quantitative calculation of 13 more variables concerning the cover percentage of each category assigned (trees and shrubs identified to species level and herbs to family or genus levels). Variables concerning vegetation height inside the circles were obtained from the 42 point measures taken (Table I).

Absence circles were randomly defined using ArcView GIS 3.2 software, and after field confirmation (tunnels and feces absence), the same microhabitat variables were monitored (Table I). In order to minimize spatial autocorrelation of data, only circles spaced at a minimum distance of 100 m were sampled (presence or absence).

From the first to the second survey period, 11 dry season presence circles were abandoned by voles and thus, data of six new colonies were obtained in the wet season survey to achieve a similar presence/absence proportion at both models.

**Data analysis:** Logistic regression models (Hosmer & Lemeshow 2000) were used to evaluate which variables were more important in predicting the Cabrera vole presence during the dry and wet seasons, separately. Univariate analyses were used for 22 habitat variables to test for differences between habitat variables in the presence and absence circles, and for variable reduction. A direct logistic regression was computed for all independent variables, while for binary and category variables, a Pearson chi-square test was used to complete information at the univariate stage. Variables were considered significant for further evaluation (at this two procedures) when  $P < 0.25$  (Hosmer & Lemeshow 2000).

Some microhabitat parameters were assessed by different methods (e.g. P\_SOIL and SOIL), which originated pairs of variables describing the same characteristic. Also, many variables describing different microhabitat parameters can usually have some degree of correlation with others. The least significant variable, of a pair of correlated variables, in the univariate tests ( $r > |0.5|$ ,  $P < 0.05$ ) or the variable with less accuracy in the measurement method, were removed from the analysis to avoid multicollinearity (Kolowski & Woolf 2002).

Autocorrelation is the lack of independence between pairs of observations at given distances in time or space

Table I. – List of independent microhabitat variables measured for modelling the Cabrera vole presence in a cork oak woodland (VE-visual estimation; LI-line intercept method).

CODE	DESCRIPTION	VALUES	TYPE	METHOD
WATER	Type of water courses	(0-absence, 1-drainage, 2-temporary, 3-permanent)	ordinal	VE
P_SOIL	Bare soil cover (%)	(0-100)	continuous	VE
P_HERB	Herbaceous vegetation cover (%)	(0-100)	continuous	VE
P_SHRUB	Shrub cover (%)	(0-100)	continuous	VE
TREE	Number of trees	(0-7)	continuous	VE
GREEN	Green <i>versus</i> dry herbaceous vegetation cover (%)	(0-100)	continuous	VE
RUBUS	Presence of <i>Rubus</i> sp (brambles)	(0/1)	binary	VE
JUNCUS	Presence of <i>Juncus</i> sp (rushes)	(0/1)	binary	VE
HETERO	Spatial distribution of herbaceous and shrub cover	(1-4)	nominal	VE
NFAMI	Number of plant families in point sampling	(1-10)	continuous	LI
SOIL	Number of sampling points in bare soil (%)	(0-100)	continuous	LI
GRASS	Number of sampling points in grass (%)	(0-100)	continuous	LI
CSALV	Number of sampling points in <i>Cistus salvifolius</i> (%)	(0-100)	continuous	LI
LEGUM	Number of sampling points in Leguminosae plants (%)	(0-100)	continuous	LI
JUNCU	Number of sampling points in Juncaceae (%)	(0-100)	continuous	LI
LAVAN	Number of sampling points in <i>Lavandula luisieri</i> (%)	(0-100)	continuous	LI
COMP	Number of sampling points in Compositae (%)	(0-100)	continuous	LI
H_HERB	Herbaceous vegetation mean height (cm)	(0-100)	continuous	LI
H_MEAN	Vegetation mean height (n=42) (cm)	(0-120)	continuous	LI
H_SD	Vegetation standard deviation height (n=42) (cm)	(3-65)	continuous	LI
H_MIN	Vegetation minimum height >0 (n=42) (cm)	(1-45)	continuous	LI
H_MAX	Vegetation maximum height (n=42) (cm)	(20-300)	continuous	LI

and is commonly found in ecological data (Legendre 1993). Although some precautions were made during field work to avoid it, a risk is always involved in assuming a non-real fact. Because spatial autocorrelation violates the assumption of independence of most statistical procedures (Legendre 1993), the Moran's I coefficient was calculated to measure spatial autocorrelation of the dependent variable, using the Rook-case, an Excel 97/2000 Add-In (Sawada 1999). Moran's I usually varies between -1 and 1 for maximum and positive autocorrelation, respectively (Legendre 1993).

All variables remaining after the screening process of the univariate testing ( $P < 0.10$ ) and multicollinearity study were entered into a logistic regression function following backward stepwise procedures (maximum likelihood method). To remove spatial autocorrelation effects of data, the geographical coordinates of the sampling circles (UTM coordinates) were considered as two explanatory variables (X and Y). Because these variable values were very high, both of them were divided by  $10^4$  to prevent very high model coefficients. Both variables and their interaction were tested in the models (Bustamante 1997) at "main effects" building stage. The criterion for variables to enter and remain in the logistic model was  $P < 0.05$  (Siriwardena *et al.* 2000, Wauters *et al.* 2001). Linearity in the logit was verified by the Box-Tidwell transformation and scatter graphs for continuous variables. Interactions were analysed and included in the final model if its coefficient remained significant ( $P < 0.05$ ) (Hosmer & Lemeshow 2000, Tabachnick & Fidell 2001).

In order to evaluate the models goodness-of-fit, G tests, Nagelkerke  $R^2$ , Pearson correlations between ob-

served and predicted outcome and Pearson chi-square statistic were considered (Brito *et al.* 1999). Furthermore, classification tables were analysed for correct model predictions for presence (sensitivity) and absence (specificity) of voles. To measure the classification accuracy, independently of the critical threshold value, receiver operating characteristic curves (ROC) were built. The area under the curve (AUC) provided a single quantitative index of the diagnostic accuracy of the models (Osborne *et al.* 2001).

The predictive power of the models was assessed using a Jack-knife analysis to compare classification values and Pearson correlation among observed values and Jack-knife predictions and among the two model predictions (Osborne & Tigar 1992, Manel *et al.* 2001).

All statistical procedures were performed with SPSS for Windows (Norusis 1997).

## RESULTS

### Dry season

After univariate analysis and data screening (Table II), six variables were excluded due to multicollinearity problems and only ten independent variables were selected to enter in the dry season multivariate model: GRASS, SOIL, TREE, HETERO, GREEN, JUNCUS, LAVAN, RUBUS,

Table II. – Mean values (min-max) of independent variables measured within 10 m-radius circles of presence and absence of the Cabrera vole and results of univariate logistic regressions (G test, significant at  $p < 0.25$ ; variable codes as in Table I).

VARIABLE CODES	DRY SEASON				WET SEASON			
	Presence	Absence	Univariate tests	P-value	Presence	Absence	Univariate tests	P-value
WATER	1 (0-2)	0 (0-2)	7.762	0.021	1 (0-2)	0 (0-2)	7.441	0.024
P_SOIL	6.59 (1-15)	39.09 (10-95)	76.080	0.000	10.00 (0-35)	34.77 (0-80)	31.884	0.000
P_HERB	54.48 (20-95)	24.33 (3-80)	32.384	0.000	49.40 (0-77)	25.82 (2-90)	19.415	0.000
P_SHRUB	39.64 (2-70)	35.97 (2-70)	0.683	0.409	36.93 (0-60)	39.41 (5-65)	0.502	0.479
TREE	2 (0-5)	5 (0-16)	20.810	0.000	2. (0-6)	4 (0-16)	10.438	0.001
GREEN	63.77 (2-98)	36.67 (5-85)	14.173	0.000	77.50 (20-95)	78.67 (20-100)	0.063	0.802
RUBUS	0 (0-1)	0 (0-1)	6.651	0.010	0 (0-1)	0 (0-1)	3.084	0.079
JUNCUS	0 (0-1)	0 (0-1)	7.924	0.005	0 (0-1)	0 (0-1)	4.594	0.032
HETERO	3 (1-4)	1 (1-4)	14.447	0.002	2 (1-3)	1 (1-3)	6.877 <sup>a</sup>	0.032
NFAMI	6 (2-10)	6 (2-9)	0.026	0.872	4.57 (2-7)	5.00 (2-8)	1.678	0.195
SOIL	2.86 (0-7)	17.55 (0-90)	42.408	0.000	1.97 (0-15)	15.03 (0-80)	24.899	0.000
GRASS	51.51 (15-90)	24.82 (0-71)	26.414	0.000	49.57 (10-88)	23.82 (0-85)	17.781	0.000
CSALV	22.11 (0-54)	27.61 (0-80)	1.266	0.260	29.50 (0-88)	36.57 (0-85)	1.759	0.185
LEGUM	4.09 (0-27)	6.24 (0-22)	1.602	0.206	0.73 (0-5)	3.85 (0-22)	15.116	0.000
JUNCU	2.43 (0-34)	0.27 (0-7)	5.998	0.014	2.50 (0-15)	0.74 (0-22)	3.523	0.061
LAVAN	1.34 (0-12)	5.00 (0-24)	7.236	0.007	2.57 (0-17)	4.23 (0-29)	1.359	0.244
COMP	4.49 (0-12)	8.03 (0-56)	3.789	0.052	3.37 (0-24)	3.95 (0-24)	0.210	0.647
H_HERB	46.49 (22-96)	39.45 (0-67)	3.269	0.071	30.53 (11-49)	23.36 (0-68)	3.853	0.050
H_MEAN	54.91 (28-94)	49.12 (5-98)	1.610	0.204	52.03 (33-81)	51.92 (1-111)	0.000	0.984
H_SD	29.29 (16-44)	32.94 (13-50)	3.262	0.071	33.57 (25-55)	34.67 (3-64)	0.168	0.682
H_MIN	14.37 (1-35)	11.15 (3-25)	3.300	0.069	8.10 (1-25)	10.08 (2-45)	0.888	0.346
H_MAX	129.29 (70-	131.21 (50-200)	0.058	0.810	139.83 (100-200)	136.03 (20-300)	0.118	0.731

<sup>a</sup> HETERO3 (two classes collapsed)

COMP and H\_HERB. The main model retained four of these variables. At this stage, geographical variables were included in the model by the same stepwise procedure and a final model was obtained, defined by: percentage of grasses (GRASS), percentage of bare soil (SOIL), percentage of green herbs (GREEN), position (X.Y) and number of trees (TREE) (Table III). There was high positive spatial autocorrelation (Moran's  $I > 0.60$ ) between data points less than 180 m distance, which explains the significance of "position" variable. The model was highly significant ( $G=75.735$ ,  $df=5$ ,  $P < 0.001$ ), with a high explanatory power (Nagelkerke  $R^2=89.6\%$ ), a very high correlation between observed and predicted outcome ( $r=0.909$ ,  $P < 0.001$ ) and low Pearson  $X^2$  value (null hypothesis not rejected), all revealing a very high model goodness-of-fit. Also, an excellent accuracy was found on the discrimination of presences from absences ( $AUC=0.987 \pm 0.010$ ,  $P < 0.001$ ).

The main model correctly classified 94.1% of the sampled circles (97.0% and 91.4% for absence and presence classifications, respectively), while the Pearson correlation between observed and predicted outcome was very high ( $r=0.909$ ,  $P < 0.01$ ). Jack-knife validation procedures resulted in 80.0% of presence circles and 72.7% of absence circles classified correctly, resulting in a 76.5% correct classification, while Pearson correlation between observed outcome and Jack-knife prediction was very satisfactory ( $r=0.548$ ,  $P < 0.01$ ). The associa-

tion between main and Jack-knife model predictions was high ( $r=0.598$ ,  $P < 0.01$ ).

High grass cover, low percentage of bare soil, availability of green herbaceous vegetation, geographical position and few surrounding trees were associated with the presence of voles in the dry season.

### Wet season

During univariate testing and data screening, the variable HETERO was transformed to three categories (Table II) and three variables were excluded because of high correlation problems. After this process, nine variables were retained for initializing the multivariate model: GRASS, SOIL, LEGUM, TREE, WATER, HETERO3, JUNCUS, H\_HERB and RUBUS. Three variables were selected in the first model and after stepwise inclusion of geographical variables a final model was obtained and defined by: percentage of bare soil (SOIL), number of trees (TREE) and percentage of leguminous plants (LEGUM) (Table III). All geographical variables were excluded from the model. The variable TREE was not linear in the logit, so it had to be transformed to  $(TREE)^2$  during model building stage. In average terms, there was low spatial autocorrelation between points (Moran's  $I < 0.20$  for points more than 140 m distance). Only one sample point presented high values of Moran's  $I$

Table III. – Top, Logistic regression model of the presence of Cabrera vole in a cork oak woodland at the dry season based on the significance of the Wald statistic (variable codes as in Table I). Bottom, Logistic regression model of the presence of Cabrera vole in a cork oak woodland at the wet season based on the significance of the Wald statistic (variable codes as in Table I).

Variable codes	B	SE	Wald test	df	sig	Exp (B)
GRASS	0.108	0.048	5.142	1	0.002	1.087
SOIL	-0.347	0.134	6.704	1	0.010	0.744
GREEN	0.071	0.035	4.100	1	0.043	1.058
POSITION (X.Y)	-0.067	0.034	3.989	1	0.046	0.935
TREE	-0.620	0.314	3.898	1	0.048	0.572
constant	1515.004	758.971	3.998	1	0.046	

  

Variable codes	B	SE	Wald test	df	sig	Exp (B)
SOIL	-0.157	0.066	5.767	1	0.016	0.854
(TREEE) <sup>2</sup>	-0.061	0.029	4.554	1	0.033	0.941
LEGUM	-0.328	0.155	4.494	1	0.034	0.720
constant	1.882	0.556	11.465	1	0.001	

( $I = -1$ ), but it was decided not to exclude it from further analysis.

The model was highly significant ( $G=38.320$ ,  $df=3$ ,  $P<0.001$ ) with a satisfactory explanatory power (Nagelkerke  $R^2=57.9\%$ ), a moderated correlation between observed and predicted outcome ( $r=0.677$ ,  $P<0.001$ ) and a low Pearson  $X^2$  value (null hypothesis not rejected), revealing a medium model goodness-of-fit. Nevertheless, the model showed a very high accuracy in discriminating presences from absences ( $AUC=0.869\pm 0.046$ ,  $P<0.001$ ).

The main model correctly classified 82.4% of circles (82.1% and 82.8%, for absence and presence circles, accordingly) and a high correlation between observed and predicted outcome was observed ( $r=0.677$ ,  $P<0.01$ ). Using Jack-knife validation procedures, overall correct classification was 81.2% (75.8% and 86.1%) and Pearson correlation was also high ( $r=0.624$ ,  $P<0.01$ ). A significant model predictive power was verified by a very high correlation between both models predictions ( $r=0.984$ ,  $P<0.01$ ).

For the wet season voles also occurred in areas with low percentage of bare soil and few trees, as well as with low abundance of leguminous plants.

## DISCUSSION

An attempt was here made to demonstrate that the Cabrera vole occurrence is greatly dependent on the microhabitat characteristic scale. The high values of goodness-of-fit obtained for both logistic

models indicate that this goal was achieved. Although the model for the wet season had lower fitness to data (suggesting that also other variables should have been included in the analysis), its predictive power was superior. This means that the wet season model is less dependent on existing data and has more power at predicting new colonies. On the other hand, the dry season model describes more efficiently the existing data, although new predictions will be less reliable (Fielding & Haworth 1995). Nevertheless, both models describe very accurately the species distribution and the most influencing microhabitat characteristics for the presence of the species at the Grândola mountain and at cork oak woodland formations, which was a major goal of this study. In future works it is desirable to increase the dimensions of the study area and the sample size, including other macrohabitat types and vegetation formations to achieve models describing colony distribution and abundance at a regional basis and with a greater predictive power.

Results indicate an association of voles with open areas where green vegetation cover (mainly grasses) is abundant, especially during the driest period of the year. These findings are in accordance with other studies (San Miguel 1992, Fernández-Salvador 1998), identically referring the importance for *M. cabreræ* of open habitats with herbaceous vegetation that remains green over the year and with formations of perennial grasses.

The relevance of vegetation cover is well known as it affords many ground-dwelling animals' shelter, food and nesting opportunities, as well as protection (e.g. Monamy & Fox 2000, Pusenius & Ostfeld 2002). Furthermore, the preference for hab-

itats with few trees near the colonies can be explained by the fact that several avian predators use trees as hunting perches (e.g. Southern & Lowe 1968, Widén 1994), although these trees could also provide high cover and protection from summer high temperatures and direct sun exposure.

Fourteen predator species that normally prey upon small mammals occur at the study area: two strigiformes, four accipitriformes and eight mammalian carnivores (King 1985, Santos-Reis & Correia 1999). The abundance of avian and mammal predators, as well as the diurnal activity of the Cabrera vole (Fernández-Salvador 1998) may also account for the significance of the herbaceous vegetation cover in avoiding predators detection (King 1985). In addition, vegetation cover may play an important role in thermoregulation, preventing from overheating, especially during the summer months (Mathias *et al.* 2003), when almost no surface water is available in Mediterranean-type habitats (Blondel & Aronson 1999). The low metabolic rate, the high thermal conductance and digestability of the species also suggests a physiological adjustment to heat and drought during the summer (Mathias *et al.* 2003, Santos *et al.* 2004). At this season, green grasses and herbs are scarce and concentrate at few sites, frequently associated with the proximity of water courses and drainage areas. This non-randomly distribution of cover and food resources during the dry season can influence colonies geographical distribution, as revealed by the higher number of colonies found at the northwestern part of the study area. Besides, the few works on Cabrera vole's diet revealed that it included more than 58% of grasses (Soriguer & Amat 1988, Costa *et al.* 2003), which may also justify their high abundance near colonies. On the other hand, San Miguel (1992) suggested the avoidance of leguminous herbaceous plants by *M. cabreræ*, which agrees with its significance in the wet season model. However, other microtines such as the American *Microtus ochrogaster* and *M. pennsylvanicus* frequently consumed leguminous plants (Marquis & Batzli 1989, Schweiger *et al.* 2000). During the wet season, green grasses are available everywhere, allowing colonies to disperse more through the area, justifying the lower values of spatial auto-correlation at this season. So, this study also demonstrated that the presence of a colony at a given location may not be constant through the year.

In addition, several dry season areas became inundated during the wet season, forcing the individuals to occupy other suitable areas. This moving behaviour is still not completely understood and several questions remain unanswered: where and how far individuals go or whether or not they return to the same summer areas. Yet, since environmental disturbances resulting from fire or plough are frequent in Mediterranean woodlands, the Cabrera vole could have developed some kind of

adaptation to cope with adverse conditions. For instance, meadow voles (*Microtus pennsylvanicus*) avoided fire, finding refuges in burrows (Geluso 1986).

Understanding the mechanisms that allow a *k*-strategist (Fernández-Salvador *et al.* 2001) and a specialist species like the Cabrera vole to deal with these frequent perturbations is essential for a future conservation strategy.

ACKNOWLEDGEMENTS. – Authors are deeply obliged to H Iglésias (Statistical and Operational Investigation Department, Faculty of Science, Lisbon) for valuable statistical support and to A P Mira for useful suggestions. Accommodation was provided by the Centre for Environmental Biology (Faculty of Science, Lisbon) at its Field Station, the Herdade da Ribeira Abaixo (Grândola). This research was supported by a SAPIENS project (POCTI/BSE/39604/2001) involving FEDER funds and a PhD fellowship from Fundação para a Ciência e Tecnologia (PRAXIS/SFRH/BD/6841/2001).

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Reçu le 20 avril 2004; received April 20, 2004

Accepté le 2 septembre 2004; accepted September 2, 2004