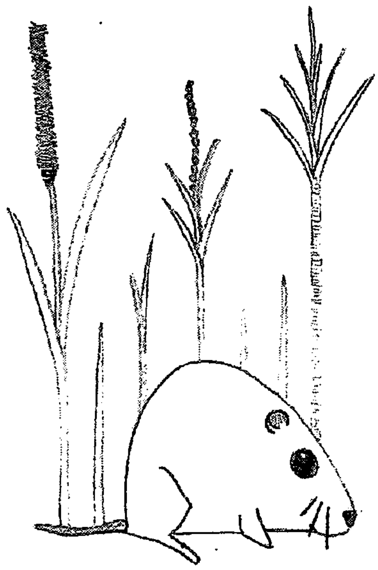
Universidade de Évora

Análise da vegetação em colónias de rato de Cabrera (*Microtus cabrerae*) no sul de Portugal



Sara Maria Lopes dos Santos

Dissertação apresentada para a obtenção do grau de mestre em Biologia da Conservação.

Orientador: Prof.ª Drª Maria Paula Simões
Co-orientador: Prof. Dr. António Mira
Co-orientador: Prof.ª Doutora Maria da Luz Mathias

Évora, 2005

Esta dissertação não inclui as criticas e sugestões feitas pelo Júri.

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AGRADECIMENTOS

Não posso deixar de agradecer às várias pessoas que contribuíram para que esta tese de mestrado fosse possível:

Ao António Mira por tanta coisa, que nem sei por onde começar: pelo entusiasmo contagiante, por me ter convencido que este mestrado de Évora era muito bom, por me ter aconselhado "escolhe uma tese que te dê gozo", por ter acreditado que eu seria capaz e por ter aceite orientar mais uma tese de mestrado;

À Profª Paula Simões por ter aceite ser minha orientadora, pela disponibilidade no esclarecimento de dúvidas taxonómicas e existenciais, pela revisão do manuscrito e comentários construtivos;

À Profª Maria da Luz Mathias por ter aceite esta orientação de tese, pelo incentivo, pela revisão crítica do manuscrito e comentários construtivos;

À Engª Helena Mafalda Carolino e equipa do Laboratório de Física de Solos, do Departamento de Fitotecnia da Universidade de Évora pela análise das amostras de solo;

À Carla Cruz pela bibliografia, disponibilidade, introdução à fitossociologia, indispensável ajuda nos métodos botânicos e curso intensivo de TWINSPAN;

Ao Dr. Manuel João Pinto por responder, a meio de Agosto, a questões sobre análise de dados de vegetação;

À Inês Rosário pela amizade, pelo incentivo e por tempos passados na Herdade da Ribeira Abaixo que levaram a este gozo de juntar a identificação das plantas e as colónias de rato de Cabrera;

Ao Paulo Cardoso pela resposta às minhas dúvidas botânicas, pelas ideias e sugestões na análise de dados, pelo interesse e incentivo;

Aos professores Isabel Ramos e Paulo Sá Sousa pelas críticas construtivas durante as sessões de Projecto & Seminário;

Ao Grupo do "Projecto & Seminário IV" pelas castanhas, jeropiga e o debate científico que se gerou;

Aos Colegas de mestrado pelos bons momentos de "regresso às aulas", ideias e trabalhos apresentados;

Ao Rui pelo apoio e incentivo constantes, por ouvir as minhas dúvidas e solucioná-las sempre, pelas amostras de solo em Agosto, por aturar as minhas rabugices de sono (e de mau feitio) e por estar sempre presente.

ÍNDICE GERAL

Análise da vegetação em colónias de rato de Cabrera (*Microtus cabrerae*) no sul de Portugal

RESUMO

O rato de Cabrera (*Microtus cabrerae*) é um roedor ameaçado da Península Ibérica com uma distribuição fragmentada e requisitos específicos de microhabitat.

Este estudo tem por objectivo documentar a composição florística das comunidades vegetais presentes em colónias do sul de Portugal, com ênfase na análise comparativa de colónias de berma de estrada e de prado, e relacionar as principais diferenças com variáveis explicativas.

Amostraram-se 26 colónias, distribuídas por cinco áreas geográficas e diversas tipologias de variáveis foram registadas: diversidade de espécies, grupos de Raunkiaer, grupos taxonómicos, topografia, perturbação e propriedades do solo.

Identificaram-se oito grupos de comunidades vegetais, incluíndo prados, arrelvados de gramíneas altas e perenes, prados intervencionados, arrelvados de gramíneas anuais e comunidades de anuais, ruderais e nitrófilas, tendo a gramínea perene *Agrostis castellana* estado presente em 92% das colónias.

As colónias de berma de estrada e de prado revelaram distintas composições florísticas. As plantas indicadoras de bermas corresponderam principalmente a gramíneas e herbáceas anuais, espécies ruderais e nitrófilas. Nos prados foram mais frequentes as gramíneas perenes e espécies indicadoras de humidade.

Palavras-chave: *Agrostis castellana,* arrelvado, berma, composição florística, habitat, *Microtus cabrerae*, prado, rato de Cabrera.

Vegetation analysis in colonies of Cabrera vole (*Microtus cabrerae*) in southern Portugal

ABSTRACT

The Cabrera vole (*Microtus cabrerae*) is a threatened rodent of the Iberian Peninsula with a patchy distribution and specific microhabitat requirements.

This study aims at documenting floristic composition of plant communities of vole colonies in southern Portugal, with emphasis on the comparative analysis of road verge and meadow colonies, and relating main differences with explanatory variables.

Sampling was conducted in 26 colonies along five geographical areas and several variables concerning diversity, Raunkiaer life-forms, taxonomic groups, topography, disturbance and soil properties were measured.

Eight vegetation community groups were identified, including meadows, tall perennial grasslands, manured meadows, annual grasslands and ruderal and nitrophilous communities. The perennial grass *Agrostis castellana* was present at 92% of colonies.

Road verge and meadow colonies showed distinct floristic composition. Indicator species of road verge colonies corresponded mainly to annual grasses and forbs, ruderal and nitrophilous species. At meadows, perennial grasses and moisture indicative species were the most common.

Key-words: *Agrostis castellana*, Cabrera vole, floristic composition, grassland, habitat, meadow, *Microtus cabrerae*, road verge.

1. INTRODUÇÃO

Os valores mais elevados de diversidade biológica são atingidos em ecossistemas mediterrânicos tradicionais, como os montados do sul da Península Ibérica (Blondel & Aronson 1999). A conservação deste património biológico implica a protecção de genes, de espécies, de habitats e de ecossistemas (Wilson 1992). Em termos gerais, a biologia da conservação assenta em dois tipos de estratégias. A primeira consiste em garantir que determinadas espécies ameaçadas tenham meios para sobreviver, pelo menos, em algumas regiões; a segunda tem por objectivo a conservação dos habitats e dos ecossistemas (Blondel & Aronson 1999). A protecção dos habitats é normalmente referida como a melhor estratégia de conservar as espécies que dele dependem (ex. Wilson 1992). Muitas são raras e endémicas, ocorrendo em áreas localizadas que frequentemente não são incluídas nas reservas e áreas protegidas de maiores dimensões. Nestes casos, a conservação das espécies exige normalmente planos de acção específicos (Blondel & Aronson 1999).

O rato de Cabrera (*Microtus cabrerae* Thomas, 1906) é um roedor endémico da Península Ibérica, com categoria de Vulnerável em Portugal e Espanha, sendo considerado uma espécie relíquia (ICN em publicação, Palomo & Gisbert 2002).

A sua distribuição actual é fragmentada (ex. Mitchel-Jones *et al.* 1999) e ocorre apenas em áreas de clima tipicamente mediterrânico (Ayanz 1992, Fernández-Salvador 1998). Localmente, forma colónias, muitas vezes de dimensões inferiores a 500 m^2 (Ayanz 1992, Santos *et al.* 2003), em comunidades vegetais que mantenham maior humidade edáfica durante o Verão, como juncais, zonas de gramíneas altas e perenes, locais com elevada densidade de herbáceas e também bermas de estrada (Ayanz 1992, Fernández-Salvador 1998, Santos *et al.* 2003). Estes locais estão frequentemente associados a áreas de montado de sobro ou azinho e policulturas (ex. Fernández-Salvador 1998, Mathias 1999) que se distribuem pelo centro, nordeste e sudoeste de Portugal Continental (figura 1). Uma colónia corresponde a um conjunto de animais que ocupam um mesmo local, com densidades que variam entre um a cinco animais por 500 m^2, dependendo da época do ano e do número de juvenis antes da dispersão (Fernández-Salvador 1998).

Dada a elevada especificidade do habitat, a distribuição da espécie, mesmo a nível local, é muito fragmentada. Frequentemente as áreas de habitat potencial para a espécie (frequentes no sopé das serras e em zonas planas) são, actualmente, utilizadas para a agricultura, pastoreio e outras actividades que, na maioria das vezes, não são compatíveis com a presença da espécie (ex. Fernández-Salvador 1998). Esta influência humana tem sido responsável pela perda de habitat, a principal causa de ameaça para a espécie (Cabral *et al.* 1990).

Apesar de ser um dos roedores ibéricos menos estudados, existem alguns trabalhos sobre a sua biologia, tais como: distribuição e macro-ecologia (ex. Ayarzagüena *et al.* 1976, Madureira 1979, Magalhães & Madureira 1980, Madureira & Ramalhinho 1981, Brunet-Lecomte 1991, García 1999, Landete-Castillejos *et al.* 2000, Cruz *et al.* 2002), morfologia (ex. Ayarzagüena & López-Martinez 1976, Ayarzagüena & Cabrera 1976, Magalhães & Madureira 1980, Brunet-Lecomte 1991), morfometria (Ventura *et al.* 1998), genética (ex. Cabrera-Millet *et al.* 1982, Burgos *et al.* 1988, Bullejos *et al.* 1996, Fernández *et al.* 2002), reprodução (Fernández-Salvador *et al.* 2001), fisiologia (Mathias *et al.* 2003, Santos *et al.* 2004), dieta (Soriguer & Amat 1988, Costa *et al.* submetido) e utilização do espaço e habitat (Ayanz 1992, Fernández-Salvador 1998, Pita *et al.* 2003, Santos *et al.* 2003). Embora a lista de trabalhos seja aparentemente extensa, este é um roedor para o qual falta ainda informação importante que permita agir com segurança na conservação do seu habitat e na elaboração de planos de acção, que necessitam de dados mais específicos sobre o habitat. Os trabalhos que relacionam as colónias com o microhabitat têm-se centrado, sobretudo, numa abordagem da vegetação em termos de estrutura e de grandes grupos taxonómicos. Em Portugal, ainda não foi tentada uma abordagem ao habitat em termos de composição florística, que seria útil no planeamento de acções de conservação.

A qualidade, composição e extensão do coberto vegetal são componentes do habitat cruciais para os micromamíferos herbívoros (ex. Doyle 1990), de tal forma que a distribuição de um animal pode ser influenciada pela presença ou ausência de determinadas espécies vegetais (Schweiger *et al.* 2000). A sua função inclui a protecção de predadores (ex. Schweiger *et al.* 2000, Pusenius & Ostfeld 2002), a protecção de condições climáticas adversas e o fornecimento de alimento (ex. Marquis & Batzli 1989).

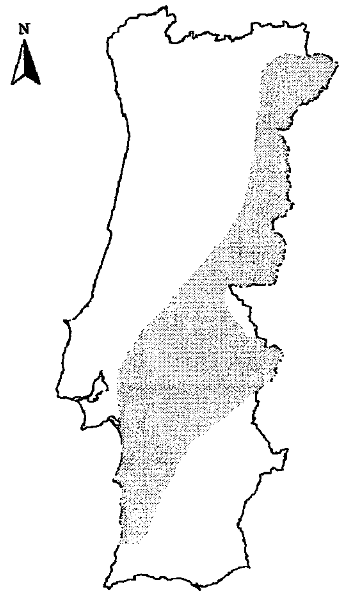

Figura 1. Mapa da distribuição do rato de Cabrera (*Microtus cabrerae*) em Portugal (adaptado de Mathias 1999; Cruz *et al.* 2002; Mira *et al.* in prep, R. Pita, dados não publicados).

A vegetação também funciona como um indicador ambiental sensível, que tem sido usado como uma medida de avaliação das condições ambientais gerais, reflectindo as características dos solos onde se encontra (ex. sais minerais, nutrientes, estrutura física) (Billings 1970). A análise das espécies e das comunidades vegetais associadas às colónias do rato de Cabrera pode permitir uma melhor compreensão dos factores ecológicos associados. Esta abordagem constitui uma ferramenta útil, a juntar a outras em processo de desenvolvimento, podendo contribuir para uma estratégia nacional de conservação da espécie. Acções como a recuperação populacional de colónias, repovoamentos ou melhoramento do habitat terão uma maior probabilidade de sucesso, se existir informação detalhada sobre as espécies herbáceas (ou outras) que são mais comuns nas colónias. Por outro lado, a análise da variabilidade inter-colónias poderá dar novas indicações acerca da plasticidade ambiental da espécie.

1.1. Objectivos

No sentido de fundamentar acções no âmbito de uma estratégia de conservação do rato de Cabrera, pretende-se, neste trabalho: (*i*) reunir informação de base sobre a composição florística das comunidades presentes em colónias de rato de Cabrera no sul de Portugal; (*ii*) distinguir grupos de colónias com maiores semelhanças florísticas entre si e relacioná-los com variáveis de estrutura da vegetação, grupos taxonómicos e fisionómicos, diversidade de espécies e grupos funcionais, grau de perturbação, topografia e propriedades do solo; (*iii*) e, por último, comparar, com maior grau de detalhe, colónias de berma de estrada e colónias de prado (afastadas da estrada), e avaliar a qualidade das bermas como habitat para o rato de Cabrera.

Para responder a estas questões, o presente trabalho será dividido em dois artigos:

1) Análise da vegetação em colónias de rato de Cabrera no sul de Portugal (*Vegetation analysis in colonies of an endangered rodent, the Cabrera vole, in southern Portugal*);

2) As bermas de estrada como habitat do rato de Cabrera: análise da vegetação (*Road verges as habitat for the Cabrera vole: a vegetation analysis*)

O primeiro artigo pretende responder às questões fundamentais, já referidas anteriormente, que deram origem a este trabalho (primeiros dois objectivos), podendo as respostas obtidas ser incluídas em planos e acções de conservação dirigidos à espécie. O segundo pretende explorar hipóteses relativas a diferenças na qualidade do habitat (espécies e abundância de gramíneas presentes) das colónias de berma de estrada, quando comparadas às colónias mais típicas (de prado). Este último objectivo surgiu na sequência das primeiras prospecções de campo, durante a fase inicial de selecção de colónias. Foi registada uma elevada percentagem de presenças em bermas de estrada, em diferentes áreas geográficas, com indícios de presença, por vezes, muito abundantes. Embora a bibliografia refira a ocorrência da espécie neste tipo de habitat (ex. Fernández-Salvador 1998), esta tipologia de colónias era ainda desconhecida em Portugal. Desde logo surgiram questões relacionadas com as razões que tornarão estas bermas atractivas para a espécie e possíveis consequências ecológicas para a mesma.

1.2 Nomenclatura utilizada

A nomenclatura das espécies vegetais foi seguida de acordo com a Nova Flora de Portugal Franco 1971, Franco 1984, Franco & Rocha-Afonso 1994, Franco & Rocha-Afonso 1998, Franco & Rocha-Afonso 2003) e a ortografia segundo a Flora Ibérica (ex. Castroviejo *et al.* 1995).

2. ANÁLISE DA VEGETAÇÃO EM COLÓNIAS DO RATO DE CABRERA NO SUL DE PORTUGAL

(submetido a "Biodiversity and Conservation")

Vegetation analysis in colonies of an endangered rodent, the Cabrera vole, in southern Portugal

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ABSTRACT

The Cabrera vole (*Microtus cabrerae*) is a threatened rodent endemic of the Iberian Peninsula with a patchy distribution and specific microhabitat requirements.

This study aimed at documenting the composition of plant communities in vole colonies in southern Portugal. Differences observed in plant species composition were also compared with vegetation structure, taxonomic and life-form groups, species and group diversity, disturbance, topography and soil properties.

Vegetation was sampled between March and July 2004, in 26 colonies occurring in five geographical areas.

Grasses was the most abundant, common and diverse family in the colonies, and the perennial grass *Agrostis castellana* was present in 92% of colonies, with a mean cover of 16% of the site. Other frequent species were *Briza maxima* (85%), *Vulpia myurus* (85%), *Gaudinia fragilis* (81%), *Leontodon* spp. (81%), *Avena barbata* (77%), *Bromus hordeaceus* (77%) and *Tolpis barbata* (77%).

Colonies were classified in eight vegetation groups that included meadows, tall perennial grasslands, manured meadows with tall sedges, annual grasslands and ruderal and nitrophilous grasslands.

Main gradients associated with composition differences were grass richness, annual and perennial grass cover, vegetation structure (herbaceous vegetation height), soil properties (texture and moisture), disturbance (ruderal species) and colony dimensions.

Results suggest that the Cabrera vole is able to exploit a wide variety of grasslands, with a varying degree of ecological disturbance. Meadows and perennial grasslands communities seem to be higher quality microhabitats for voles.

Key-words: *Agrostis castellana*, *Microtus cabrerae*, floristic composition, grassland, habitat, Indicator Species Analysis, meadow, ordination methods, TWINSPAN.

INTRODUCTION

The Cabrera vole (*Microtus cabrerae* THOMAS, 1906) is an endemic and threatened rodent for the Iberian Peninsula with Vulnerable category in Portugal and Spain (Portuguese Red Data Book, in press, Palomo and Gisbert 2002). The species is distributed along the supra, meso and thermomediterranean bioclimatic belts of the Iberian Peninsula (Ventura et al. 1998, Rivas-Martinez et al. 2002a), from Portugal to the Iberian Prepyrenees (Ventura et al. 1998, Mathias 1999). The areas of occurrence in Portugal include cork oak (*Quercus suber*) and holm oak (*Q. rotundifolia*) open woodlands as main habitat, which are under European Union's legal protection (European Commission 1999).

Locally, populations are grouped in colonies, often restricted to areas of reduced dimensions (often less than 500 m^2), showing a patchy distribution (Ayanz 1992, Fernández-Salvador 1998). Main threats to the species include habitat loss, which leads to highly fragmented populations (Fernández-Salvador 1998).

Implementation of action plans and management decisions towards a species conservation, require detailed knowledge of the preferred habitat and the main resources required by the species, such as food, shelter, water or nesting sites (Caughley and Sinclair 1994). Some of these resources are related with vegetation structure and species composition (e.g. Lin and Batzli 2001). One of the most important habitat components for a herbivorous small mammal is the vegetation, namely its cover, extension and quality (e.g. Doyle 1990, Lin and Batzli 2001), once some plant species may influence the animal's presence or absence (Schweiger et al. 2000). However, studies relating floristic composition of habitats and small mammals requirements are rare or absent (Dooley and Bowers 1996, Burel et al. 2004).

Research has been conducted towards the definition of habitat structure and vegetation characteristics suitable for the Cabrera vole, although reporting to small geographical areas. This species prefers open areas with high herbaceous vegetation cover, high green grass cover especially in the summer, and low height of shrubs (Pita et al. 2003, Santos et al. in press).

The main goal of this study was to gather data on the composition of plant communities in Cabrera vole colonies in southern Portugal, as a main step towards the definition of a conservation strategy for the species. We also intend to group colonies according to their vegetation similarities and relate differences with variables concerning vegetation structure, taxonomic and life-form groups, species and group diversity, disturbance, topography and soil properties. On the other hand, only a small number of colonies is, presently, known and monitored, so this work will complement general information about colonies in Portugal and verify the amplitude diversity of the Cabrera vole's habitat.

METHODS

Study areas

Five study areas (Alandroal, Mora, Ciborro, Cabrela and Grândola) were investigated in southern of Portugal (Alentejo province) along an east-west longitudinal belt of about 120 km long, from the Spanish border to the Atlantic coast (7°25'W-8°25'W and 38°08'N-38°55'N) (figure 1).

The climate is Mediterranean with annual rainfall from 500 to 800 mm (Grândola 700-800 mm and Alandroal 500-700 mm), mean annual temperatures from 15 to 17.5°C (Grândola 16-17.5°C and the remaining areas 15-16°C) and insolation values from 2800 to 3100 h per year (Alandroal more than 3000 h, and Cabrela, Ciborro and Mora 2800-2900 h) (Instituto do Ambiente 1995). The study areas are included in the thermomediterranean and mesomediterranean belts (Rivas-Martínez et al. 2002a) with elevation values under 300 m a.s.l. and soils mainly acid (Instituto do Ambiente 1995).

The dominant land use is the traditional open woodland designated 'montado', with cork or holm oaks, that combines extensive agriculture, forestry and livestock grazing (Pinto-Correia 1993). High grazing pressure and shrub clearing are the major disturbances in these ecological systems (Pinto-Correia and Vos 2002).

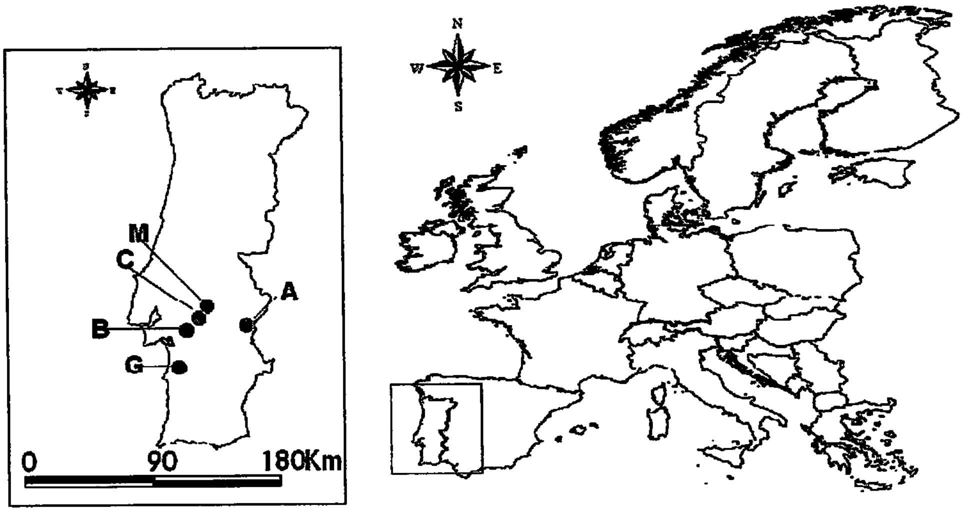

Figure 1. Location of the study areas (G: Grândola, B: Cabrela, C: Ciborro, M: Mora, A: Alandroal).

Colonies identification

A survey of Cabrera vole colonies was conducted during February and March 2004 on potential habitats: sedge/rush communities, herbaceous areas located near small drainage streams, meadows with high soil moisture and high perennial grasses, and road verges (e.g. Fernández-Salvador 1998, Mathias 1999, Landete-Castillejos et al. 2000).

Vole presence signs, such as runways, fresh droppings and grass clippings, were used for delimitation of colonies and area calculation (Ayanz 1992, Delattre et al. 1996, Fernández-Salvador 1998, Lambin et al. 2000). This is a commonly used methodology to determine the occurrence of species of difficult capture, such as the Cabrera vole (Fernández-Salvador et al. 2001, Pita et al. 2003, Santos et al. in press). Only colonies occupying areas of at least 100 m^2 were considered in this study.

A vole abundance class was attributed to every colony on the basis of the presence signs, as follows:

1 - 'rare': few tunnels, presence of scattered old feces, latrines rare or difficult to find, and no nibbled grass;

2 - 'common': few or abundant tunnels, where feces and latrines are more easy to find, few fresh feces or fresh nibbled grass;

3 - 'abundant': abundant tunnels, latrines and feces very easy to find, abundance of fresh nibbled grass and fresh feces;

4 - 'very abundant': very abundant tunnels, latrines, fresh feces, fresh nibbled grass, all very easy to find (adapt. Ayanz 1992).

Vegetation sampling at the colonies

The vegetation survey was performed in 26 colonies from March to July 2004. A second visit was necessary in most colonies (n=20), in order to identify both early and late flowering species.

Two complementary methods were used in vegetation surveying. Species composition and abundance of tree and shrub strata were determined by searching for every species growing in each colony. The tree stratum included all woody species higher than 3 m height; the shrub stratum corresponded to all woody species under 3 m in height (Humphries et al. 1996). Individual cover and height of trees and shrubs were calculated by visual estimation and averaged to an overall percentage for the colony (Bullock 1996). Herbaceous vegetation was surveyed in 1 × 1 m plots, by stratified random sampling (e.g. Sorrels and Glenn 1991, Kent and Coker 1992). Colonies were stratified by differences in slopes, soil moisture, soil type or the existence of marked differences in vegetation structure (Elzinga et al. 1998).

Three to six plots were distributed along each colony and per visit, according to number of strata defined and dimensions (three/four plots for areas from 100 to 300 m^2, five plots for 300 to 600 m^2 areas, and six plots for areas above 600 m^2) (Duffy and Meier 1995).

Cover and height of all herbaceous species were recorded in each plot. Total canopy cover proportions of the herbaceous vegetation and bare ground were assessed by eye (0-100%).

A total of 113 plots was sampled in a first visit and 78 plots in the second (21+14 at Grândola, 21+8 at Cabrela, 22+19 at Ciborro, 27+27 at Mora and 22+10 at Alandroal, respectively).

Nomenclature of the plant taxa followed 'Nova Flora de Portugal' (Franco 1971, Franco 1984, Franco and Rocha-Afonso 1994, Franco and Rocha-Afonso 1998, Franco and Rocha-Afonso 2003). A few taxa (e.g. *Leontodon* spp. and *Carlina* spp.) were identified only to genus level. Others (e.g. *Poa* spp., *Vicia* spp., *Galium* spp.) were identified to species, but pooled after to genus level. The non-woody *Scirpoides holoschoenus* was included in the shrub category for simplicity on data management.

Explanatory variables

Environmental information for each colony was also recorded, including elevation, aspect, slope, drainage stream presence, grazing signs presence and distance to the nearest paved road.

Species richness was calculated for each colony by summing up the number of herbaceous species identified, as well as the Shannon diversity index H' and corresponding evenness (Brower et al. 1990). Number of herbaceous and grass species per m^2, and of shrub species per 100 m^2 were also calculated for each colony.

Species were classified into several categories according to Raunkiaer life-forms (Kent and Coker 1992, Lavorel et al. 1997). Some of these categories were further divided in taxonomic groups (hemicryptophytes graminoids or therophytes graminoids; Dupré and Diekmann 2001, Jantunen and Saarinen 2002). Number of species with moisture and/or soak affinity was registered, as well as ruderal and nitrophilous species. All categories assigned were based on previously cited references (Franco 1971, Franco 1984, Franco and Rocha-Afonso 1994, Franco and Rocha-Afonso 1998, Franco and Rocha-Afonso 2003) and others (Valdés et al. 1987, Duarte et al. 2002).

In every colony, one or two random soil samples of 400-500 g were taken during August 2004, according to the apparent soil heterogeneity. These samples were collected at 15-20 cm depth and, after air-dried and mixed, were used to analyse soil texture (sand, silt and clay) pH, and organic matter and nitrogen content. Undisturbed soil samples were also taken for water retention at the same points with three replicates of steel sample rings (Reeuwijk 2002). Total number of soil samples collected was 35 and number of steel rings was 105. Soil texture was determined by X-ray diffractometry (Kimpe 1993, Reeuwijk 2002). Soil pH was obtained with pH meter and distilled water (Reeuwijk 2002). Organic matter content and total nitrogen were determined by dry combustion method (McGill and Figueiredo 1993) using LECO Carbon and Nitrogen analysers. Soil moisture holding capacity (pF) was obtained through pressure plate extractors (pF 2.54 or field capacity) (Reeuwijk 2002).

Data analysis

Species abundance for each vole colony was evaluated by averaging cover per species for individual plots.

Plant composition was analysed by colony. Comparisons of species, taxonomic and functional group abundances and explanatory variables between geographical areas, were conducted with non-parametric Kruskal-Wallis tests, multiple comparison Q tests and Spearman rank correlations (Zar 1999). Non-parametric tests were preferred because of small sample sizes.

Similarities between colonies were evaluated by the divisive and polythetic method, TWINSPAN (two-way indicator species analysis; Hill 1979). The ranges of cover were defined by cut-levels of 1, 5, 10 and 25% in the analysis (Peet et al. 1999, Jackson and Bartolome 2002). First default cover classes were doubled to minimize leveraging by rare species (Jackson and Bartolome 2002). Classification was stopped at the fourth level so that the size of stands would demonstrate ecological meaning and divisions with eigenvalues lower than 0.20 were discarded (Cowlishaw and Davies 1997, Jackson and Bartolome 2002). Eigenvalues approximated the proportion of pseudospecies not common to each group and provide a precise criterion for determining the merit of each division (Jongman et al. 1995). Once the colonies had been classified by TWINSPAN, groups were validated by multiresponse permutation procedures (MRPP) that compares global species composition between two or more groups (McCune and Mefford 1999, Muotka et al. 2002); and species importance was verified by indicator species analysis (ISA) that calculates for each defined group an indicator value for all species (Dufrêne and Legendre 1997). The ISA analysis also aimed the validation of indicator species proposed by TWINSPAN. Both methods (MRPP and ISA) use distribution-free Monte Carlo tests to achieve statistical significance (499 permutations) and require groups with a minimum of two colonies (McCune and Mefford 1999).

Identification of dominant vegetation communities of each TWINSPAN group followed Rivas-Martínez et al. (2002b). Names given to each group intended to synthesize a great amount of information for an easier interpretation and, although based on the cited reference, had no phytosociological purposes.

TWINSPAN groups were ordered according to main revealed gradients (e.g. moisture, perennial cover, etc.) and Spearman rank correlation coefficient was used to evaluate the relationship between those groups and each explanatory variable.

Ordination was used in part to confirm if the classification results adequately reflected the floristic gradients in the data and also to reveal the relationships between explanatory variables and the composition of the vegetation. Two ordination methods were applied: detrended correspondence analysis (DCA; Hill and Gauch 1980) and canonical correspondence analysis (CCA; ter Braak 1986). Cover percentage of each herbaceous species was used as a floristic value on both classification and ordination analyses without transformations (Moustafa and Zaghloul 1996). DCA was performed with downweight of rare species (Cowlishaw and Davies 1997) and detrending by segments options (Jongman et al. 1995). The DCA performed on data showed that the first axis had a gradient length of 2.9 SD, suggesting that species' responses may be moderately unimodal (Jongman et al. 1995).

Canonical ordination techniques are designed to detect the patterns of variation in the species data that are best explained by the observed variables (Jongman et al. 1995). Variables were centred and standardised to obtain zero mean and unit variance (ter Braak 1986). Significance of species-environment correlation was tested by the distribution-free Monte Carlo test (499 permutations). Ordination axes were interpreted using the intraset correlations that allow inference on the relative importance of each variable for predicting community composition (ter Braak 1986).

Twenty-five variables were considered for entering the CCA ordination (table 1). Due to the small number of colonies, only 18 variables were retained (ter Braak 1986) after a compromise of obtaining the maximum percentage of variance explained and the significance of both eigenvalues and correlations of species-explanatory variables with the axes.

PC-ORD version 4 (McCune and Mefford 1999) was used for TWINSPAN, MRPP, Species Indicator Analysis, DCA and CCA. CANOCO for Windows version 4.5 (ter Braak and Šmilauer 2002) was only used for DCA and CCA plots, once it allows the representation of binary environmental variables. SPSS 10.0 (SPSS, Inc. 1999) was used for all other ordinary statistical analyses. Significance is reported at $\alpha=0.05$ level, unless noted otherwise in the text.

Table 1. Description of the 25 explanatory variables measured in this study (Code and meaning description).

CODE	DESCRIPTION
N	North exposure (0/1)
H	Shannon's diversity measure of herbaceous species
J	Herbaceous species evenness
S	Total number of species of all layers
SG_m	Grass species richness per m^2
shr_100	Shrub species richness per 100 m^2
her_m	Herbaceous species richness per m^2
tree	Total tree cover (%)
shr	Total shrub cover (%)
md_hh	Mean herbaceous height (m)
ruder	Proportion of ruderal species compared to total colony richness (%)
graz	Presence of grazing signs (0/1)
D_roa	Distance to the nearest paved road (m)
moist	Proportion of moisture indicator species compared to total colony richness (%)
GHM	Hemicryptophyte (perennial) grasses cover (%)
GT	Therophyte (annual) grasses cover (%)
S_rau	Richness of Raunkiaer life-form groups
ph	Soil pH
sand	Sand content in the soil (%)
clay	Clay content in the soil (%)
pf2	Soil field capacity (water retention)
orgm	Organic matter content in the soil (%)
nitr	Nitrogen content in the soil (%)
dim	Dimensions of the colony (m^2)
abun	Vole abundance class (1-4)

RESULTS

Colonies characteristics

A total of 26 colonies was considered for the present study: five at Grândola, Cabrela, Ciborro and Alandroal and six at Mora. Dimensions of colonies averaged 485 m^2 (100 to 2450 m^2) and vole abundance classes varied between 'abundant' (34.6% of colonies), 'common' (30.8%), 'rare' (27%) and 'very abundant' (7.6%). With respect to these two characteristics (dimensions and abundance), no significant differences were found between the medians of the five geographical areas (Kruskal-Wallis tests: $H=1.754$, $P>0.05$; $H=4.305$, $P>0.05$, respectively).

Colony sites were at 170 m a.s.l. of median elevation (35-281 m), in flat areas with very small slopes (57.7% of colonies) and were localized at small drainage streams (77% of colonies). Alandroal presented the highest median elevation values (239 m) when compared to Cabrela and Mora (153 and 133 m, respectively) (K-W: H= 13.2, $P<0.01$; Q tests: Q=2.811, $P<0.05$, Q=3.308, $P<0.01$). Differences on presence of slopes and small drainage streams between areas were not found (Phi tests: $\Phi=0.265$, $P>0.05$; $\Phi=0.547$, $P>0.05$, respectively). Aspect varied between North, East and South. West facing colonies (NW, W or SW) were not registered.

Main land uses in the surroundings of colonies were cork oak 'montado' (61.5%) and holm oak 'montado' (30.8%). The cork oak was dominant in Grândola, Cabrela and Ciborro, the holm oak in Alandroal, and Mora presented both woodland types. Although the landscape matrix was mainly 'montado', the surroundings of some colonies also showed different land uses, such as crop fields, *Eucalyptus* spp. plantations and *Pinus pinaster* mosaics.

The presence of grazing inside or adjacent to the colonies was rare and occasional over the year. Grazing signs (mainly sheep) were detected at 15.4% of the colonies (n=4), in all geographical areas, except in Cabrela.

Global vegetation description and species richness

Most common vegetation structure registered in colonies was herbaceous stratum with several small dispersed shrubs (or one central and a large group), although only herbaceous colonies and shrubby colonies were also identified. The three situations occurred in all geographical areas. Only two colonies were characterized by a dominant tree stratum.

Overall, 208 plant species were identified in Cabrera vole colonies (Appendix 1). Species richness ranged from 6.4 to 14.3 species per m^2, for all layers and showed no significant differences in medians between geographical areas (K-W: H=4.534, $P>0.05$). Herbaceous diversity and evenness ranged from 1.21 to 3.29 and 0.39 to 0.84, respectively, with median values of 2.5 (diversity) and 0.70 (evenness). No significant differences between geographical areas were found (K-W: H=7.364, $P>0.05$; H=5.961, $P>0.05$).

Figure 2 represents the average cover of main vegetation functional groups for the studied colonies. Grasses show the highest cover values in all geographical areas. Shrubs also show an important cover in all areas. From the seven vegetation groups defined, only legumes cover differed between areas, being more abundant in Alandroal (K-W: H=13.900, $P<0.05$; Q=3.432, $P<0.05$).

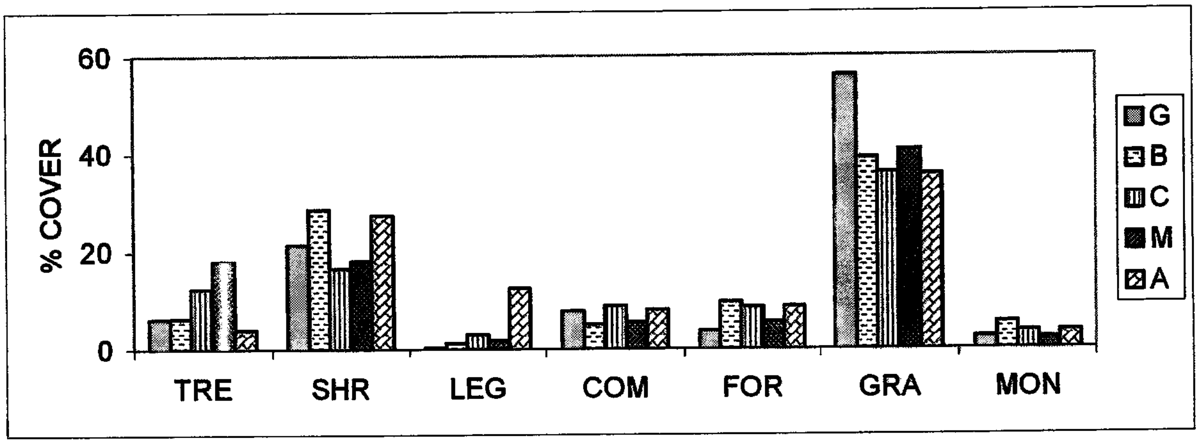

Figure 2. Average cover of main vegetation functional groups in the five studied geographical areas (TRE: Trees, SHR: shrubs, LEG: Legumes, COM: Composites, FOR: forbs that includes other dicot species besides legumes and composites, MON: other mocot species besides grasses; G: Grândola, B: Cabrela, C: Ciborro, M: Mora, A: Alandroal).

Thirty-one woody species were identified: six in the tree layer and 25 in the shrub layer. In average, each colony included one tree species (0 - 3) and five shrub species (0 - 14). The most common trees were *Quercus suber* (62%) and *Quercus rotundifolia* (27%), while the most frequent shrubs were *Scirpoides holoschoenus* (46%), *Cistus ladanifer* (42%), *Dittrichia viscosa* (42%), *Lavandula luisieri* (42%), *Asparagus aphyllus* (42%), *C. salviifolius* (38%) and *Rubus ulmifolius* (35%) (Appendix 1). Median cover values of woody species were 4% (0-70%) and 28% (1-60%), for trees and shrubs, respectively. Differences between the five areas were not significant for both trees and shrubs cover values (K-W: H=9.121, P>0.05; H=1.736, P>0.05, respectively).

A total of 177 herbaceous species was surveyed. Families with higher species richness were *Gramineae* (n=39), *Leguminosae* (n=30) and *Compositae* (n=27). Forty-four percent of the species recorded were perennials (hemicryptophytes, geophytes and helophytes; n=77).

Number of herbaceous species per m^2 (plot) ranged from 6.8 to 26.3. Considering the median values, no significant differences between the five areas were found for this characteristic (K-W: H=6.357, P>0.05).

Most frequent herbaceous species were *Agrostis castellana* (92%), *Briza maxima* (85%), *Vulpia myurus* (85%), *Gaudinia fragilis* (81%), *Leontodon* spp. (81%), *Avena barbata* (77%), *Bromus hordeaceus* (77%) and *Tolpis barbata* (77%). Of these, only *A. castellana* presented mean cover values as high as 16% of total colony area (considering only the colonies where it occurs). In a global view, this value is only exceeded by woody species (Appendix 1).

In what concerns the herbaceous layer, comparisons between colonies revealed significant differences in vegetation composition between Grândola and Alandroal (MRPP test: T=-2.143, P<0.05) and between Mora and Alandroal (T=-2.765, P<0.05). The remaining paired combinations of colonies revealed no significant differences (P>0.05).

Multivariate analysis

Classification of colonies

A total of 152 herbaceous species, belonguing to 33 families, was used in the analysis.

The dendrogram produced by TWINSPAN analysis revealed eight vegetation groups at the fourth level (figure 3, table 2). All eigenvalues were considered satisfactory ($\lambda \geq 0.400$). First level of the analysis separated a group of colonies with high cover values of perennial grasses and low cover of annual species (groups I to III; n=10). The other group was characterized by higher herbaceous species diversity and evenness, high abundance of annual grasses and annual or ruderal forbs (groups IV to VIII; n=16). *Agrostis castellana* and *Festuca ampla* were the indicator species for the first group (ISA: IV=75.5%, P<0.01; IV=56.4, P<0.01, accordingly), and second group was defined by the presence of *Bromus madritensis*, *Gaudinia fragilis*, *Medicago* spp. and *Geranium dissectum* (ISA by the same order: IV=79.9%, P<0.01; IV=64.8%, P<0.05; IV=79.0, P<0.01; IV=61.4%, P>0.05). Groups obtained were defined as follows:

I- Subhumid meadows with *Agrostis castellana* and *Festuca ampla*;

II- Subhumid meadows with tall sedges and *Agrostis castellana*;

III- Tall and perennial grasslands with *Agrostis castellana* and *Brachypodium phoenicoides*;

IV- Annual grasslands with *Brachypodium phoenicoides* and *Holcus lanatus*;

V- Manured meadows with tall sedges and *Phalaris coerulescens*;

VI- Manured meadows with brambles and *Holcus lanatus*;

VII- Annual grasslands with *Bromus diandrus* and *Avena barbata*;

VIII- Annual, ruderal and nitrophilous communities.

Group I was characterized by meadow colonies with high cover values of perennial grasses, namely *A. castellana* and *F. ampla*, along with several moisture indicator species and low species diversity (figure 3, table 2). Groups **II** and **III** included colonies with high cover of *A. castellana* accompanied by *Vulpia* spp. or *F. ampla* (group II) or *Brachypodium phoenicoides*. Group II had higher moisture conditions than group III due to the indicator presence of *Juncus acutiflorus* and *Hypericum humifusum*, and also higher cover of *A. castellana*. On the other side of the first level division, group **IV** presented high cover values of *B. phoenicoides* and *Holcus lanatus*, followed by other annual grasses like *B. madritensis*. Groups **V** and **VI** were characterized by intermediate cover of perennial grasses and abundance of moisture indicator species. Group V was characterized by high cover of *Phalaris coerulescens*, total grasses, and presence of *Lotus* spp. and ruderal species. On the other side is group VI defined by high cover of *H. lanatus*. Groups **VII** and **VIII** had the greatest abundance values of annual grasses like *Vulpia* spp., *Bromus* spp. and *Holcus annuus*; group VII with higher cover of *A. castellana*, *Bromus diandrus* and *Avena barbata*, although *Bromus tectorum* and *Taeniatherum caput-medusae* were the significant indicator species. The last TWINSPAN group is VIII that included the highest number of ruderal species and annual herbs diversity. Ten significant indicator species (mostly forbs) were identified by ISA, three of them being also ruderal species (table 2, appendix 1).

There were significant differences in all four division levels considered in the MRPP tests, *i.e.*, between the two first groups ($T=-7.401$, $P<0.001$), between the four second groups ($T=-5.981$, $P<0.001$), between the intermediate six groups ($T=-6.082$, $P<0.001$) and for the final eight groups ($T=-5.856$, $P<0.001$). Group VI could not be compared statistically (MRPP and ISA) with the other groups (figure 3).

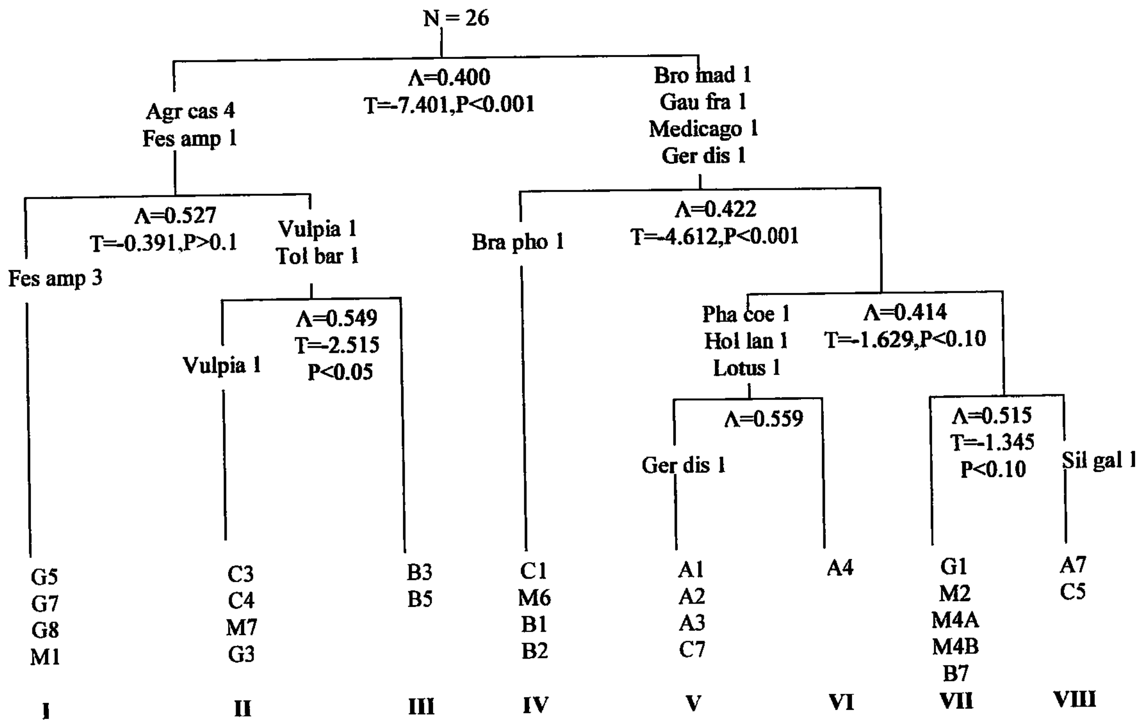

Figure 3. Results of the TWINSPAN analysis and MRPP tests (λ). (Indicator species produced by the analysis - Agr cas: *Agrostis castellana*, Fes amp: *Festuca ampla*, Bro mad: *Bromus madritensis*, Gau fra: *Gaudinia fragilis*, Medicago: *Medicago* spp., Ger dis: *Geranium dissectum*, Vulpia: *Vulpia* spp., Tol bar: *Tolpis barbata*, Bra pho: *Brachypodium phoenicoides*, Pha coe: *Phalaris coerulescens*, Hol lan: *Holcus lanatus*, Lotus: *Lotus* spp., Sil gal: *Silene gallica* (numbers after species correspond to cut-level cover classes); Vegetation groups - I: Subhumid meadows with *Agrostis castellana* and *Festuca ampla*; II: Subhumid meadows with tall sedges with *Agrostis castellana*; III: Tall and perennial grasslands with *Agrostis castellana* and *Brachypodium phoenicoides*; IV: Annual grasslands with *Brachypodium phoenicoides* and *Holcus lanatus*; V: Manured meadows with tall sedges and *Phalaris coerulescens*; VI: Manured meadows with brambles and *Holcus lanatus*; VII: Annual grasslands with *Bromus diandrus* and *Avena barbata*; VIII: Annual, ruderal and nitrophilous communities).

Table 2. Results of indicator species analysis (ISA), with indicator values (IV) for the eight TWINSPAN groups and significance (*P<0.05, **P<0.01) (see figure 3 for groups names).

Group	Indicator species	%IV
I	*Festuca ampla*	57.1*
	Mentha pulegium	37.1
	Serapias lingua	19.1
II	*Juncus acutiflorus*	73.4*
	Rumex angiocarpus	68.3*
	Tuberaria guttata	60.9*
	Agrostis castellana	29.7
	Hypericum humifusum	29.6
	Scilla ramburei	27.8
	Hypochaeris radicata	25.8
III	*Gladiolus illyricus*	100*
	Asphodelus spp	74.3*
	Brachypodium phoenicoides	73.9*
	Linum bienne	63.7**
IV	*Bromus madritensis*	73.5**
	Sherardia arvensis	60.5
	Cynosurus echinatus	59.3*
	Cynara humilis	53.9*
	Holcus lanatus	52.4
	Torilis spp.	44.9
	Vicia spp.	40.4
	Logfia gallica	29.4
	Sanguisorba minor	22.7
V	*Lotus* spp.	99.4**
	Geranium dissectum	65.8*
	Lolium rigidum	61.2*
	Phalaris coerulescens	47.3*
	Daucus spp.	41.1
	Senecio spp.	23.6
VI	-	-
VII	*Bromus tectorum*	60.0*
	Taeniatherum caput-medusae	60.0*
	Bromus diandrus	40.7
	Avena barbata	30.5
VIII	*Siline gallica*	90.7**
	Plantago lagopus	88.5**
	Echium plantagineum	87.4**
	Hedypnois cretica	74.1**
	Trifolium angustifolium	70.3*
	Hordeum murinum	63.2*
	Medicago spp.	60.9*
	Raphanus raphanistrum	60.1*
	Crepis spp.	48.0*
	Gaudinia fragilis	44.4*

Colony dimensions were also significantly higher in group II (subhumid meadows with tall sedges) when compared to groups IV and VII (annual grasslands) (KW:

H=16.172, P<0.05; Q tests:Q=2.888, P<0.05; Q=3.109, P<0.05, respectively) and an area decrease was verified towards group VIII (Spearman correlation: r_s = -0.489, P<0.05). No significant differences in vole abundance classes were registered between the eight groups and there was no correlation across the groups ranking (KW: H=5.402, P>0.05; r_s =0.097, P>0.05).

Ordination of colonies

Figure 4 presents the DCA ordination results of the herbaceous data. The eigenvalues were 0.448 for first axis and 0.322 for the second. Axis 1 separated colonies with higher perennial grass cover like *Agrostis castellana* (groups I and II) from opposite colonies' characteristics (groups IV and VIII). The second DCA axis revealed a moisture gradient, discriminating between the wettest colonies at the plot bottom (groups I and V) from the drier colonies at the top (group III). TWINSPAN groups are recognizable in the DCA figure, albeit the existence of some overlap between groups V and VII.

The CCA ordination results are plotted in figure 5. The axes presented eigenvalues of 0.474 (P<0.01) for the first and 0.398 (P=0.06, near statistical significance) for the second axis, both axes accounted for 20.0% of the total variance in species data. Pearson correlations between species and explanatory variables were high (0.995 and 0.975), but only significant for the first axis (P<0.01).

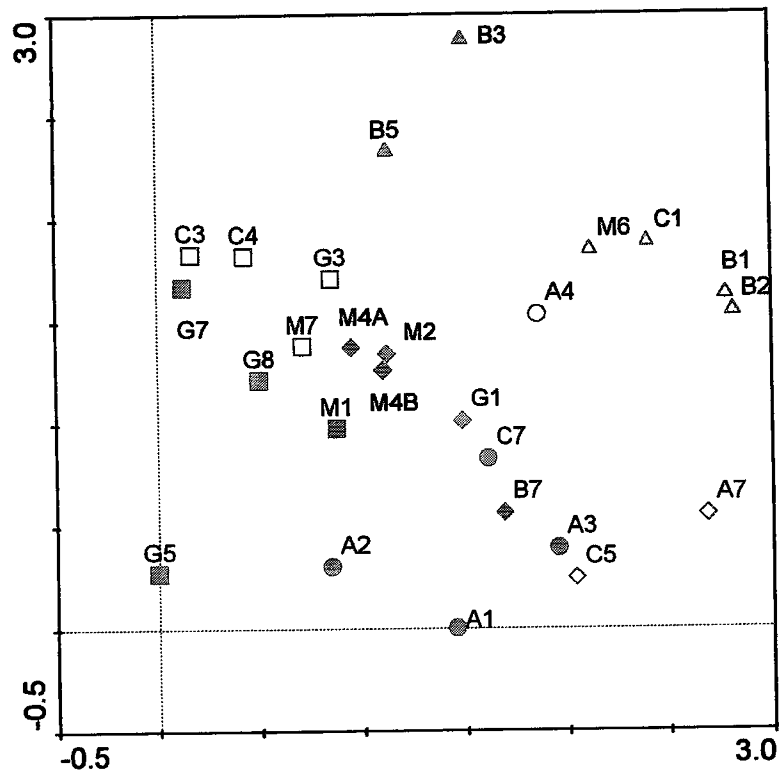

Figure 4. Results of the DCA ordination (full square: Subhumid meadows with *Agrostis castellana* and *Festuca ampla*; empty square: Subhumid meadows with tall sedges with *Agrostis castellana*; full triangle: Tall and perennial grasslands with *Agrostis castellana* and *Brachypodium phoenicoides*; empty triangle: Annual grasslands with *Brachypodium phoenicoides* and *Holcus lanatus*; full circle: Manured meadows with tall sedges and *Phalaris coerulescens*; empty circle: Manured meadows with brambles and *Holcus lanatus*; full diamond: Annual grasslands with *Bromus diandrus* and *Avena barbata*; empty diamond: Annual, ruderal and nitrophilous communities).

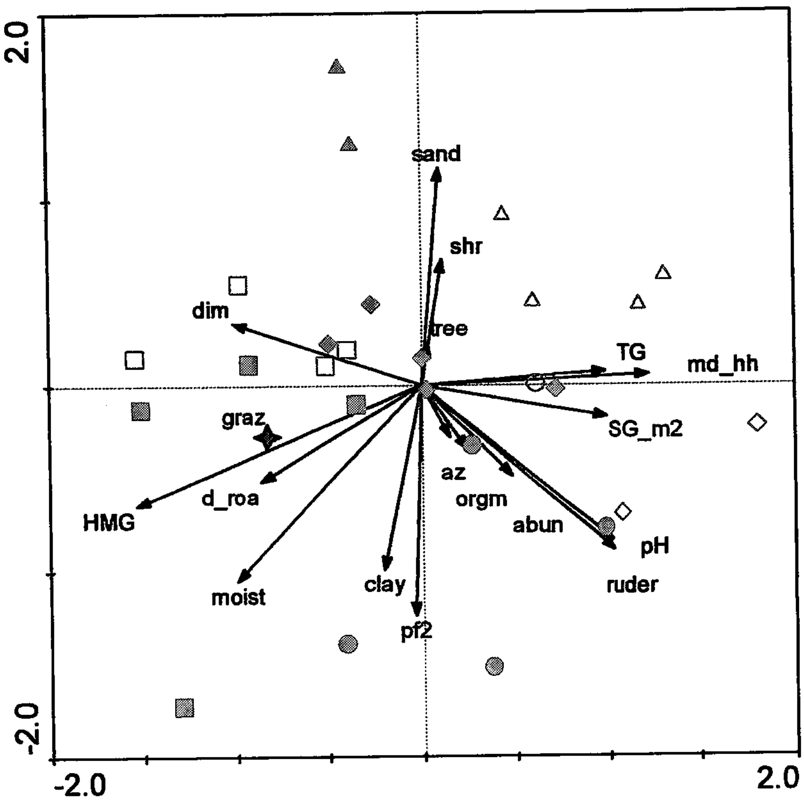

Figure 5. Results of CCA ordination (symbol codes for colony groups as in figure 4; vectors with arrows are explanatory variables - SG_m2: grass richness per m^2; HMG: perennial grass cover; TG: annual grass cover, d_roa: road distance; md_hh: mean herbaceous height; tree: tree cover; shr: shrub cover; ruder: percentage of ruderal species; moist: percentage of moisture indicator species; clay: soil clay content; sand: soil sand content; nitr: soil nitrogen content; pH: soil pH; orgm: soil organic matter content; pf2: soil field capacity; dim: colony dimension; abun: vole abundance class; full star represents one binary variable graz: grazing presence).

The first axis was highly correlated with perennial grass cover, distance to road, colony dimensions, soil pH, ruderal species percentage, mean herbaceous height and grass species richness. The second axis is more correlated with soil field capacity, moisture indicator species percentage, and sand and clay content in the soil (table 3).

At the top right of the diagram quadrant (figure 5) is group IV (annual grasslands) that is described by high values of annual grass cover, mean herbaceous height, grass richness per m^2, shrub and tree cover, sandy soils, and low values of perennial grass cover, moisture indicator species, distance to road, colony dimensions and no grazing signs. Group III (tall and perennial grasslands) is represented on the top left quadrant and is characterized also by high sand content in the soil, cover of shrubs and trees, but high colony dimensions and low soil field capacity and clay content, pH, organic matter, nitrogen, ruderal species and vole abundance. Biophysical characteristics of remaining groups are according to this view.

The observed correspondence in the eigenvalues and colonies relative position in the figures between the DCA and CCA ordinations, reveals that studied explanatory variables are suitable for explaining the differences in herbaceous vegetation composition between groups of colonies.

Table 3. Correlations (*r*) between axes of species and explanatory variables from the canonical correspondence analysis (CCA) (intraset correlation) (see figure 5 for variables legend).

Variable	Axis 1	Axis 2	Axis 3
SG_m2	-0.519	0.005	0.113
HMG	0.757	0.421	-0.247
TG	-0.492	-0.116	0.496
d_roa	0.560	0.243	-0.112
md_hh	-0.587	-0.024	-0.117
tree	0.012	-0.129	-0.328
shr	-0.038	-0.313	-0.370
ruder	-0.567	0.400	0.174
moist	0.465	0.626	-0.012
graz	0.427	0.191	0.140
sand	0.033	-0.614	0.251
clay	0.033	0.522	-0.321
nitr	-0.095	0.151	-0.331
ph	-0.575	0.425	-0.129
orgm	-0.165	0.178	-0.538
pf2	-0.060	0.650	-0.156
dim	0.540	-0.115	0.196
abun	-0.254	0.230	0.147

DISCUSSION

General characteristics of colonies

Understanding general characteristics of vole colonies can be relevant for national management plans. Our findings revealed that most colonies occupy less than 500 m^2, are localized in edaphohigrophilous vegetation communities dominated by grasses and have no preference by aspect position, which is also supported by Ayanz (1992). On the other hand, elevation values of Portuguese colonies are lower (35 to 281 m) than those reported by the same author (260 to 1520 m). This happens because the Portuguese study areas belong to a 'lowlands' region of the Iberian Peninsula (Alentejo). Another distinctive characteristic is the high abundance of cork oak 'montado' in Portugal, which is rarer in Spain (Natividade 1990). Habitat and vegetation descriptions of colonies occurring in the thermomediterranean belt are new data for the Iberian Peninsula, as most Spanish colonies are within the mesomediterranean belt (Fernández-Salvador 1998, Rivas-Martínez et al. 2002a).

Floristic composition of colonies

Dominant vegetation at the Cabrera vole colonies was an herbaceous stratum with several small shrubs or just one large central shrub, the most frequently being *Scirpoides holoschoenus*, *Cistus ladanifer*, *Dittrichia viscosa* or *Lavandula luisieri*. Most common plant species at the colonies were *Agrostis castellana*, *Brixa maxima*, *Vulpia myuros*, *Gaudinia fragilis* and *Leontodon* spp. (>80%). Ayanz (1992) refers few species of high frequence (>80%), namely *A. castellana* at silicious soils and *Brachypodium phoenicoides* and *Scirpoides holoschoenus* at calcareous soils (not registered in the present study). Also most frequent species in the present study were found at low frequencies in Spain (<20%) and some were not registered at all, like *Quercus suber*, *Phalaris coerulescens*, *Agrostis pourretii* or *Serapias lingua* (Ayanz 1992). These differences can be explained by both higher sample size in Spain and vegetation differences in distinct biogeographic regions, conducting to a higher variability in Spanish data.

Explanatory variables

The two ordinations performed reflect a gradient of disturbance in the first axes, separating the meadows and tall perennial grasslands from the annual grasslands and fringe or synantropic vegetation. The analysis of the CCA diagram revealed that colonies at subhumid meadows and tall perennial grasslands (groups I, II and III) had higher area dimensions. On the other hand, greater colony dimensions were positively associated with distance to road and grazing presence, and negatively associated with mean herbaceous height, annual grass cover, grasses richness per m^2, proportion of ruderal species and soil pH. This might indicate that those groups (I to III) may correspond to colonies with higher habitat quality for voles.

CCA analysis explained relatively little of the total variance in the data, a typical characteristic of this kind of analyses that can be attributed to high noise levels of species-abundance data (ter Braak 1986). Other variables could have been included, such as climatic ones or land management history. However, precise rainfall or temperature data were difficult to obtain, as well as reliable quantification of grazing impact in the studied colonies.

Colonies of all geographical areas are present at both sides of community types (perennial vs. annual). Nevertheless, Grândola and Mora vegetation compositions revealed significant differences when compared to Alandroal (see also CCA ordination diagrams). This latter region is located in the south-east limit of the Cabrera vole distribution area in Portugal, and colonies seem to be more fragmented and localized (possibly due to lower availability of high quality habitat), which is suggested by the higher difficulty in finding colonies in this region. This situation doesn't seem to occur in any of the other geographical areas, as colonies are easier to find in diverse ecological conditions (S.M. Santos, pers. obs.).

The Cabrera vole parameters under study, were dimensions of the colonies (occupied area) and an activity index based on number and type of presence signs (see methods section). This last variable is the only approximation ever done to establish a relationship between vole signs and its abundance in the colony (Ayanz 1992), but it was never validated with trapping data. Although it may be positively correlated with number of animals in the colony, it varies through the year (Ayanz 1992) and with colony dimensions (smaller colonies tend to have higher spatial concentrated presence signs). Although, it was decided to include presence signs in the analyses, dimension of the colonies might be a better indicator for colony 'quality'. A colony that extends itself over 1500 m^2, should have more quantity and diversity of resources (shelter, food and others), along with a higher number of possible territories (higher abundance of voles) that can provide emigrant individuals to colonize smaller ones, possibly acting as a source, within a metapopulation system (Krohne 1997, Hanski 2001, Lin and Batzli 2001).

A study on meadow voles (*Microtus pennsylvanicus*) revealed a strong association between the abundance of voles and coverage of *Festuca* spp. (Dooley and Bowers 1989). In fact, permanent grasslands have been associated with low intensified agriculture landscapes and habitat quality for small mammals (Burel et al. 2004), and areas dominated by long-lived perennials can prevent the climate-driven floristic fluctuations between years, typical of herbaceous-dominated systems of the Mediterranean (Lavorel et al. 1994, Sternberg et al. 2000, Aguado-Santacruz et al. 2002). This suggests that perennial grasslands can provide more stability in the habitat, even if most plant species rarely cross barriers such as roads or fields and are dependent upon the absence of severe soil disturbances in the habitat, once they are frequently dependent upon bulbs, rhizomes or stolons for re-colonization (Sutherland 1995, Burel et al. 2004).

The subhumid meadows and manured meadows with sedges have higher probabilities of keeping moisture conditions (high number of moisture indicator species and higher values of clay and soil field capacity), reducing water stress during the summer, when compared to the other described colony types (e.g. Rodríguez-Rojo and Sánchez-Mata 2004). Although Cabrera vole has developed physiological strategies to cope with dry mediterranean conditions (Mathias et al. 2003, Santos et al. 2004), being a microtine grazer, it is still dependent on fresh grass to obtain water for metabolism (MacArthur 1972). Colonies with higher moisture conditions allow higher food quality for voles (Noy-Meir et al. 1989, Caughley and Sinclair 1994) for longer periods.

High cover of trees and shrubs were associated with tall perennial grasslands and some annual grasslands with low moisture conditions, possibly providing microclimate characteristics that avoid high water losses from the soil and herbs. Nevertheless, most colonies were located at sites with high moisture retention characteristics when compared to surrounding areas (e.g. small drainage streams). Indeed, many colonies (n=17) revealed presence of vestigial mediterranean temporary ponds, a priority habitat included in the Habitats Directive (European Commission 1999), distributed across all eight vegetation groups identified and across all five geographical areas. Most common characteristic species were *Agrostis pourretii* and *Serapias lingua* (but also *Juncus bufonius*, *J. capitatus*, *J. pygmaeus* and *Illecebrum verticillatum*). Overall, ten meadow colonies included this type of priority habitat (six subhumid and four manured meadows). In four annual grasslands and even in both colonies of ruderal communities this habitat was also recognizable. However, the corresponding dimensions, within the colony limits, was reduced.

Some of the most common grass species in the present study (>80%) are referred as main food items of the Cabrera vole (*Vulpia* spp., *A. castellana*, *Bromus* spp. and *Briza maxima*) varying from 1.7 to 24.2% of identified items, even if their cover availability in the colony is less than 1% (Soriguer and Amat 1988, Costa et al. submit). Other consumed items include *Holcus lanatus*, *Avena barbata*, *Bromus diandrus*, *Phalaris* spp. and *Scirpoides* spp. (Soriguer and Amat 1988, Costa et al. submit), all frequent in the present study colonies (>40%). This information indicates that most consumed grasses are mainly annuals, which seems to be contradictory with the high ecological value given here to the subhumid meadows. Unfortunately, this diet information is limited to a pair of colonies, one with no data on plant species availability (Soriguer and Amat 1988) and the other referring to an annual grassland-like colony (Costa et al. submit). Because studies on experimental food choice are lacking, it is unknown if voles 'select' subhumid meadows for food, microclimate conditions, vegetation structure or shelter characteristics. Nevertheless, diet studies have obtained very poor results, as only 13% to 19% of the faecal fragments could be identified to genus level (Soriguer and Amat 1988, Costa et al. submit.).

Although annual grasslands (and even ruderals) can provide enough quality food for voles, if perennial grasses are scarce, they do not provide green food during the dry season. Besides this, high abundance of annuals indicates frequent disturbances (Lavorel et al. 1997, Schweiger et al. 2000, Dupré and Diekmann 2001), like mowing and ploughing, which conduct to an increased risk of colony destruction or area reduction. These type of disturbances were shown to decrease voles home-ranges (*M. arvalis* and *M. canicaudus*) (Wolff et al. 1997, Jacob and Hempel 2003). The higher plant diversity and soil pH and nutrients values, often associated with these annuals-dominated colonies, also suggested a greater intensity of human use and disturbance at these areas (Pitkänen 2000, Shackleton 2000, Boutin et al. 2002, Critchley et al. 2002). Although grazing was associated, in this study, with subhumid meadows and manured meadows with sedges, its historical presence could not be determined and the observed signs seemed to be occasional. Several authors concluded that grazed areas have, in average, high cover of annual forbs and lower cover of perennial grasses and forbs and geophytes (e.g. Noy-Meir et al. 1989, Dupré and Diekmann 2001). This clearly suggests that the 'grazed colonies' in the present study are, in fact, areas with very occasional presence of grazers (sheep), once overgrazing is referred as a threat to Cabrera voles' habitat (Pita et al. 2004). Accordingly with Noy-Meir et al. (1989), and Dupré and Diekmann (2001) in similar studies, the legumes abundance in manured meadows (Alandroal area), may indicate that these colonies had some grazing in the past. No grazing signs were observed in colonies with presence of taxa typical of high grazed sites, which suggests that either they were grazed in the past, or the reason for their presence was another type of disturbance.

The mean height of herbaceous layer varied between intermediate values (32-45 cm) and high values (45-56 cm). The latter ones were registered in annual grasslands and ruderal nitrophilous communities, with fast-growing species. All values obtained agree with findings on the Cabrera vole preference for high vegetation cover and height above 25 cm (Fernández-Salvador 1998, Pita et al. 2003, Santos et al. in press), a situation more common in non-grazed areas (Noy-Meir et al. 1989).

Several annual grasslands and ruderal and nitrophilous communities were located at road verges, explaining the abundance of annual and ruderal species (Lavorel et al. 1997, Lugo and Gucinski 2000, Schweiger et al. 2000). This road proximity may be associated with a lack of optimal habitat in other areas, as these colonies are often separated by fences from adjacent high grazed areas or farming fields (Santos et al. in prep). Albeit these road verges seem to be sub optimal habitat for Cabrera voles, they might have a corridor function when searching for optimal areas (Soulé and Gilpin 1991, Lugo and Gucinski 2000). On the other hand, five (41.7%) of these colonies and surroundings were ploughed in summer by road maintenance works, conducting to reductions of 20 to 100% of previous colony dimensions. This type of intervention is common in the 'montado' systems (Pinto-Correia 1993) and in some road verges (Fernández-Salvador 1998).

CONCLUSION

This study shows that the Cabrera vole occupies several types of meadows and grasslands with varying floristic compositions, moisture conditions, soil properties and disturbance, providing specific data on the variability of the species' habitat in Portugal. The plant communities include: subhumid meadows, tall perennial grasslands, perennial grasslands, annual grasslands, manured meadows with tall sedges or brambles, and ruderal nitrophilous and annual communities. Higher habitat quality, like colony dimensions, seems to be associated with meadows and perennial grasslands with *Agrostis castellana, Festuca ampla*, *Brachypodium phoenicoides*, *Phalaris coerulescens* and *Holcus lanatus* as main indicator species.

The close relationship between vole colonies and mediterranean temporary ponds was an interesting result, being indicative of specific ecological requirements of the species. This association has high conservation value, once only a limited number of Portuguese colonies are presently known, and mapping of these habitats may help colony surveys.

A possible increase in number of colonies in sub optimal habitats may be of conservation concern. In regions with more intensified agriculture and livestock production, verge habitats (hedgerows, field margins, roadsides, set asides) could be the only available habitat for the Cabrera vole. Comparisons of vole's fitness (abundance, survival, reproduction parameters) in meadows or perennial grasslands, with the one in annual grasslands or road verges is an important issue to be investigated in order to understand the real impact of these activities on vole populations.

The abundance of meadows and perennial grasslands should be considered in future 'montado' management and in assessing the importance of different colonies for conservation within an area. An effort should be undertaken to prevent intensive and large scale ploughing in the 'montados' (with protection of small drainage streams) and to reduce the width of the mowed strip verges in order to minimize damage in road verge colonies.

ACKNOWLEDGEMENTS

We are mostly grateful to Soils Physics Laboratory of Phytotechny Department of University of Évora, for all soil analyses and especially to Helena Mafalda Carolino. We also thank Carla Cruz for help in the botanical methods, Manuel João Pinto for valuable suggestions, Paulo Cardoso for helpful advise in data analyses, Inês Rosário for support and valuable discussions, and Rui Lourenço for support, encouragement, scientific discussions and help in the field work.

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Appendix 1. List of species identified inside Cabrera vole colonies in southern of Portugal (Freq%: percentage of occurrence frequency; Cover%: mean percentage of cover where it occurs; LF: Raunkiaer life-form (MS: mesophanerophyte, MC: microphanerophyte, NN: nanophanerophyte, C: chamaephyte, G: geophyte, HL: helophyte, HM: hemicryptophyte, T: therophyte); Group: functional group (T: tree, S: shrub, L: legume, C: compositae, G: grass, F: other forb, M: other monocot); Indicator: ecological indicator (M: moisture, N: nitrophily, R: ruderality); and Areas: geographical areas of occurrence (G: Grândola, B: Cabrela, C: Ciborro, M: Mora, A: Alandroal).

Species list	Freq %	Cover %	LF	Group	Indicator	Areas
Agrostis castellana	92	16	HM	G		All
Briza maxima	85	1	T	G		All
Vulpia myuros	85	3	T	G		All
Leontodon spp.	81	2	HM/G	C	M	All
Gaudinia fragilis	81	1	T	G	M	All
Avena barbata	77	2	T	G		All
Bromus hordeaceus	77	1	T	G		All
Tolpis barbata	77	1	T	C		All
Galactites tomentosa	65	1	T	C	N	All
Linum bienne	65	1	HM	F		All
Quercus suber	62	8	MS	T		All
Bromus madritensis	62	3	T	G		All
Geranium dissectum	62	1	T	F	R	All
Sonchus oleraceus	62	1	HM	C	R	All
Briza minor	62	< 1	T	G	M	G,B,M,A
Stachys arvensis	62	< 1	T	F	R	All
Andryala integrifolia	58	< 1	HM	C	R	All
Anagallis arvensis	54	< 1	T	F		All
Cynodon dactylon	54	2	HM	G	M,R	All
Phalaris coerulescens	50	8	HM	G	M	All
Bromus diandrus	50	2	T	G		B,C,M,A
Hypochaeris radicata	50	< 1	HM	C	M	G,B,C,M
Scirpoides holoschoenus	46	7	G	S	M	all
Asphodelus spp.	46	3	G	M		All
Holcus lanatus	46	2	HM	G	M	B,C,M,A
Sherardia arvensis	46	1	T	F	M,R	all
Crepis spp.	46	< 1	HM	C		All
Cistus ladanifer	42	13	NN	S		All
Dittrichia viscosa	42	4	C	S	R	G,B,C,M
Dactylis glomerata	42	3	HM	G	M	G,B,C,A
Lavandula luisieri	42	3	C	S		B,C,M,A
Vulpia geniculata	42	3	T	G		All
Asparagus aphyllus	42	2	NN	S		B,C,M,A
Medicago lupulina	42	2	HM	L		G,C,M,A
Brachypodium distachyon	42	1	T	G		G,B,M,A
Daucus carota	42	1	HM	F		All
Mentha pulegium	42	1	HM	F	M	G,C,M,A
Sanguisorba minor	42	< 1	HM	F		All
Tuberaria guttata	42	< 1	T	F		All
Cistus salviifolius	38	9	NN	S		G,B,C,M
Coleostephus myconis	38	1	T	C		G,B,C,A
Plantago lanceolata	38	1	HM	F	M,R	G,B,C,A
Rumex bucephalophorus	38	< 1	HM	F		B,C,M,A
Rubus ulmifolius	35	8	NN	S	M	All
Carlina spp.	35	3	HM,G	C		All
Medicago nigra	35	3	T	L		B,C,M,A
Cynosurus echinatus	35	1	T	G		B,C,M

Appendix 1. Continued.

Species list	Freq %	Cover %	LF	Group	Indicator	Areas
Scorpiurus vermiculatus	35	1	T	L		B,C,M,A
Cerastium glomeratum	35	< 1	T	F	N,R	All
Holcus annuus	31	2	T	G		G,C,M
Agrostis pourretii	31	1	T	G	M	G,B,C,A
Rumex angiocarpus	31	1	HM	F		G,C,M
Euphorbia spp.	31	< 1	T	F		All
Serapias lingua	31	< 1	G	M	M	All
Vicia sativa	31	< 1	T	L		G,C,M,A
Festuca ampla	27	9	HM	G	M	G,C,M
Quercus rotundifolia	27	9	MS	T		B,C,M,A
Ulex parviflorus	27	3	NN	S		B,C,M
Senecio jacobaea	27	1	HM	C	M,N	G,C,M,A
Trifolium angustifolium	27	1	T	L	R	C,M,A
Vicia lutea	27	1	T	L	R	C,M,A
Crepis capillaris	27	< 1	HM	C		C,M,A
Brachypodium phoenicoides	23	9	HM	G		B,C,M
Convolvus arvensis	23	1	T	F		B,C,M,A
Cynara humilis	23	1	HM	C		G,B,C,A
Echium plantagineum	23	1	HM	F	M	B,C,M,A
Lolium rigidum	23	1	T	G		B,C,A
Hypericum humifusum	23	< 1	HM	F	M	G,B,C,M
Ornithopus compressus	23	< 1	T	L	R	C,M,A
Raphanus raphanistrum	23	< 1	T	F	R	B,C,M,A
Myrtus communis	19	4	MC	S		G,B,M
Plantago lagopus	19	3	HM	F		B,C,A
Chamaemelum nobile	19	2	HM	C	M	G,B,C
Bromus rigidus	19	1	T	G		G,B,C,A
Calendula arvensis	19	1	T	C	R	B,M,A
Cyperus longus	19	1	G	M	M	G,C,A
Daphne gnidium	19	1	NN	S		B,M
Geranium molle	19	1	T	F	R	B,C,M
Pullicaria paludosa	19	1	T	C	M	G,C,M,A
Scilla ramburei	19	1	G	M	M	G,B,C
Aristolochia longa	19	< 1	HM	F	R	G,B,M,A
Gynandriris sisyrinchium	19	< 1	G	M		B,M,A
Lathyrus angulatus	19	< 1	T	L	M	G,M,A
Parentucellia viscosa	19	< 1	T	F	M	C,M,A
Campanula lusitanica	15	< 1	T	F		B,M,A
Hedypnois cretica	15	3	T	C		B,C,A
Pyrus bourgaeana	15	2	MC	S		G,B,M,A
Genista triacanthos	15	1	NN	S		B,C,M
Holcus mollis	15	1	HM	G	M	G,M
Juncus acutiflorus	15	1	HM	M	M	G,C,M
Silene gallica	15	1	T	F		B,C,A
Lythrum spp.	15	< 1	HM,T	F	M	C,A
Sonchus asper	15	< 1	HM	C	M,N	G,C,A
Taeniatherum caput-medusae	15	< 1	T	G		M,A
Cistus crispus	12	5	NN	S		B,M
Poa trivialis	12	5	HM	G	M	G,A
Bromus tectorum	12	3	T	G	N	M
Trifolium striatum	12	3	T	L	M	M,A
Chamaemelum fuscatum	12	1	T	C	M	C,M
Chamaemelum mixtum	12	< 1	T	C	R	C,A
Galium murale	12	< 1	T	F	R	G

Appendix 1. Continued.

Species list	Freq %	Cover %	LF	Group	Indicator	Areas
Gladiolus illyricus	12	< 1	G	M		B,A
Hordeum murinum	12	< 1	T	G	R	B,C,A
Hypericum perforatum	12	< 1	C	S		C,M
Jasione montana	12	< 1	HM	F		B,M
Logfia gallica	12	< 1	T	C		B,C
Myosotis discolor	12	< 1	T	F	M	G,A
Ononis cintrana	12	< 1	T	L		B,M
Lygos sphaerocarpa	8	13	NN	S		M,A
Pinus pinaster	8	7	MS	T		B,M
Cistus monspeliensis	8	4	NN	S		C,M
Aegilops neglecta	8	3	T	G		B,M
Anthoxanthum aristatum	8	3	T	G	M	C
Carex flacca	8	3	HM	M	M	G,A
Ranunculus bulbosus	8	2	G	F	M	G,A
Carum verticillatum	8	1	HM	F	M	C,M
Galium aparine	8	1	T	F		B
Helichrysum sp.	8	1	C	C		B
Juncus pygmaeus	8	1	T	M	M	G,C
Phagnalon sp.	8	1	C	C		B,M
Pistacia lentiscus	8	1	MC	S		B,M
Carex divulsa	8	< 1	HM	M	M	A
Centaurium erythraea	8	< 1	HM	F		B,A
Galium decipiens	8	< 1	T	F		C,A
Kickxia cirrhosa	8	< 1	T	F	M	C,M
Lathyrus sativus	8	< 1	T	L		M,A
Linum trigynum	8	< 1	T	F		B,M
Lotus parviflorus	8	< 1	T	L		C,A
Oenanthe crocata	8	< 1	G	F	M	G,A
Polypogon maritimus	8	< 1	T	G		A
Teesdalia coronopifolia	8	< 1	T	F	M	G,M
Thapsia garganica	8	< 1	HM	F		B,M
Trifolium arvensis	8	< 1	T	L	N,R	M,A
Trifolium stellatum	8	< 1	T	L	R	A
Vicia villosa	8	< 1	T	L	R	C,A
Eucalyptus camaldulensis	4	41	MS	T		M
Arrhenatherum album	4	8	HM	G		G
Oxalis pes-caprae	4	8	G	F		B
Eleocharis palustris	4	7	HL	M	M	C
Cytisus baeticus	4	5	MC	S		B
Erica umbellata	4	4	NN	S		B
Lotus subbiflorus	4	3	T	L	M	C
Rumex pulcher	4	3	HM	F	R	B
Stipa gigantea	4	3	HM	G		C
Trifolium cherleri	4	3	T	L		A
Arbutus unedo	4	2	MC	S		B
Fraxinus angustifolia	4	2	MC	S	M	A
Trifolium resupinatum	4	2	T	L	M	A
Trifolium squamosum	4	2	T	L	M	A
Trifolium subbterraneum	4	2	T	L	M	A
Bromus lanceolatus	4	1	T	G		C
Carex muricata	4	1	HM	M		A
Chamomilla aurea	4	1	T	C	N,R	G
Chicorium endivia	4	1	HM	C		C
Erica arborea	4	1	MC	S	M	M

Appendix 1. Continued.

Species list	Freq %	Cover %	LF	Group	Indicator	Areas
Foeniculum vulgare	4	1	HM	F		C
Halimium ocymoides	4	1	NN	S		B
Phillyrea angustifolia	4	1	NN	S		B
Pinus pinea	4	1	MS	T		M
Quercus lusitanica	4	1	MC	S		B
Reichardia picroides	4	1	HM	F		B
Scabiosa atropurpurea	4	1	HM	F	N,R	A
Senecio lividus	4	1	T	C		M
Torilis arvensis	4	1	T	F	N,R	M
Trifolium repens	4	1	HM	L		B
Ulex minor	4	1	NN	S	M	C
Vicia benghalensis	4	1	T	L		C
Aira caryophyllea	4	< 1	T	G		G
Allium sp.	4	< 1	G	M		M
Anthoxanthum odoratum	4	< 1	HM	G	M	G
Arisarum sp.	4	< 1	G	M		A
Avenula sulcata	4	< 1	HM	G		B
Bellardia trixago	4	< 1	T	F		C
Bellis sylvestris	4	< 1	HM	C	M	G
Brassica barrelieri	4	< 1	T	F		M
Cardamine hirsuta	4	< 1	T	F	M	M
Carduus tenuiflorus	4	< 1	HM	C	N,R	A
Centaurium maritimum	4	< 1	HM	F	M	B
Crepis vesicaria	4	< 1	HM	C		M
Daucus crinitus	4	< 1	HM	F		A
Erodium botrys	4	< 1	T	F	R	M
Erodium moschatum	4	< 1	T	F	R	C
Galium divaricatum	4	< 1	T	F	R	C
Gastridium ventricosum	4	< 1	T	G		A
Geranium purpureum	4	< 1	T	F	R	C
Illecebrum verticillatum	4	< 1	T	F	M	M
Juncus bufonius	4	< 1	T	M	M	A
Juncus capitatus	4	< 1	T	M	M	G
Juncus emmanuelis	4	< 1	HM	M	HL	G
Lathyrus amphicarpos	4	< 1	T	L		B
Lathyrus cicera	4	< 1	T	L		C
Lathyrus clymenum	4	< 1	T	L		M
Linum strictum	4	< 1	T	F		A
Lotus uliginosus	4	< 1	HM	L	M	A
Lupinus angustifolius	4	< 1	T	L		M
Mentha suaveolens	4	< 1	HM	F	M,R	A
Muscari comosum	4	< 1	G	M		M
Poa annua	4	< 1	T	G	N	A
Poa infirma	4	< 1	T	G	R	M
Ranunculus gregarius	4	< 1	G	F	M	G
Rumex conglomeratus	4	< 1	HM	F	N,R	C
Rumex obtusifolius	4	< 1	HM	F	M,N	B
Scilla monophyllos	4	< 1	G	M		B
Scorpiurus muricatus	4	< 1	T	L		A
Silene laeta	4	< 1	T	F	M	G
Tulipa sp.	4	< 1	G	M		G
Vicia laxiflora	4	< 1	T	L		G
Vicia vicioides	4	< 1	T	L		G

3. AS BERMAS DE ESTRADA COMO HABITAT DO RATO DE CABRERA: ANÁLISE DA VEGETAÇÃO

(submetido a "Acta Theriologica")

Road verges as habitat for the Cabrera vole: a vegetation analysis

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ABSTRACT

The Cabrera vole (*Microtus cabrerae* THOMAS 1906) is a threatened rodent showing a fragmented distribution along the Iberian Peninsula, that occurs in areas of tall grasses and meadows. Although specific microhabitat requirements have been pointed out for the species, road verges are sometimes occupied. This study aimed the identification and comparison of the floristic composition between road verge and meadow colonies. Vegetation was sampled in 26 colonies in five geographical areas. Cover of herbaceous stratum was sampled in plots of 1x1 m. Several variables concerning plant diversity, Raunkiaer life-forms, taxonomic groups, disturbance and soil properties were measured. Data analysis was undertaken with Mann-Whitney tests and ordination techniques (DCA and CCA). Road verge and meadow colonies of Cabrera vole showed differentiated herbaceous vegetation composition. Indicator species of road verge colonies corresponded mainly to annual grasses and forbs, ruderal and nitrophilous species, along with a few perennials. In meadows, perennial grasses and moisture indicative species were more common. Although road verges had shown higher diversity in the most usually consumed grasses in the vole's diet, they evidenced several disadvantages as an habitat, such as higher disturbance, lower moisture availability during the summer and reduced colony dimensions. Possible ecological consequences of road verge management are discussed in the light of species conservation goals.

Key-words: floristic composition, Indicator Species Analysis, linear habitats, *Microtus cabrerae*, Portugal.

INTRODUCTION

The Cabrera vole (*Microtus cabrerae* THOMAS 1906) is an endemic rodent for the Iberian Peninsula, distributed along the Iberian mediterranean region, and listed in Portugal and Spain as Vulnerable (Portuguese Red Data Book, in press, Palomo and Gisbert 2002). The species occurs locally in small colonies, often of less than 500 m^2 (Ayanz 1992, Fernández-Salvador 1998). Main habitat requirements of the species include high grass cover and height, associated with meadow areas, rush/sedge communities and grasslands with high moisture conditions during the dry season (Ayanz 1992, Fernández-Salvador 1998, Landete-Castillejos *et al.* 2000, Pita *et al.* 2003). These habitat types are patchy distributed showing a varying degree of connectivity and are frequently surrounded by sub optimal or inhospitable habitats.

Fragmentation and destruction of natural habitats is currently considered to be the major threat to wildlife populations (Johannesen *et al.* 2003). At local and regional scales, land-use changes are among the most immediate drivers of species diversity. The major threat to Cabrera vole conservation was referred to be habitat loss and destruction through many activities such as grazing, fire, ploughing and agriculture conversion (Fernández-Salvador 1998, Pita *et al.* 2004, S.M. Santos, unpubl.), leading to an increased fragmentation of populations.

The Cabrera vole is considered a specialist herbivore, consuming mostly grasses and other monocotyledons in high proportions (Soriguer and Amat 1988, Costa *et al.* 2003). Although just a few diet studies on the species have been carried out, it is believed that voles consume the available grass species occurring within the colony limits (Soriguer and Amat 1988).

During a previous survey of the species distribution in southern Portugal (S.M. Santos, in prep.), the frequent occurrence of well established colonies in road verge habitats was registered. Although the issue has been highlighted in a recent study in Spain (Fernández-Salvador 1998), this is a new situation for Portugal and besides the high frequency of occurrence was unexpected.

Several studies, in the last decades, referred the ecological value of hedgerows and field margins for biodiversity (Marshall and Moonen 2002), and in particular flora (McCollin *et al.* 2000, Boutin *et al.* 2002, Aude *et al.* 2004) and fauna. Many contributions focused on bird communities (MacDonald and Johnson 1995, Parish *et al.* 1995, Fuller *et al.* 2001), and a fewer on small mammals (Paillat and Butet 1996, Tattersall *et al.* 2002).

Data reporting the ecological value of road verges for small mammals are even more scarce (Bellamy *et al.* 2000, Brock and Kelt 2004). Roads can have a significant negative impact on the environment by transversing areas of suitable wildlife habitat, and are one of the most destructive elements in the habitat fragmentation processs. However, they can also have an important ecological corridor function (Bennett 1991, Viles and Rosier 2001).

The main goal of our study is to evaluate the importance of road verges as habitats for the Cabrera vole. To achieve it, we addressed the following questions: 1) does vegetation composition differs between colonies in road verges and colonies in meadows? 2) which plant species can be regarded as "road verge" indicators? 3) how vegetation differences between road verges and meadows correlate with explanatory variables? 4) how these differences are expected to affect Cabrera vole ecological requirements?

To answer these questions, floristic composition was studied in road verge colonies and compared with meadow colonies data. Understanding the community composition of these two colony types migth lead to the understanding of the disturbance regimes that play in these environments.

STUDY AREA

This study was carried out in five geographical areas of southern Portugal (Alandroal, Mora, Ciborro, Cabrela and Grândola; 7°25'W-8°25'W to 38°08'N-38°55'N), along an east-west longitudinal belt from the Spanish border to the Atlantic coast of about 120 km.

The climate is Mediterranean with annual rainfall of 500 to 800 mm (Grândola with 700-800 mm and Alandroal with 500-700 mm), mean annual temperatures of 15 to 17.5°C (Grândola with 16-17.5°C and the remaining areas with 15-16°C) and insolation values of 2800 to 3100 h per year (Alandroal with more than 3000 h, and Cabrela, Ciborro and Mora with 2800-2900 h). All areas are under 300 m a.s.l. and soils are mainly acid (Environmental Institute 1995).

Main landscape corresponds to the Iberian open woodland of cork or holm oak (*Quercus suber* and *Q. rotundifolia*), designated "montado" (Pinto-Correia and Mascarenhas 1999). Dominant land uses are extensive agriculture (cereal, fodder), cattle and sheep grazing, hunting and forestry (Pinto-Correia and Mascarenhas 1999). High livestock densities and intensive shrub clearing are the main disturbances to these systems (Pinto-Correia and Vos 2002).

MATERIAL AND METHODS

Colonies identification

Cabrera vole colonies were surveyed between February and March 2004 in potential habitat areas: small drainage streams with high perennial grasses, grass meadows with high soil moisture, and road verges (e.g. Fernández-Salvador 1998, Mathias 1999).

Colonies were identified by vole presence signs: runways, fresh droppings and grass clippings (Ayanz 1992, Delattre *et al.* 1996, Fernández-Salvador 1998, Lambin *et al.* 2000). On the basis of these presence signs, a vole abundance class, in a scale from 1 to 4, was attributed to each colony (adapt. Ayanz 1992) and the area occupied by each one was estimated.

In each study area, a value of 100 m^2 was established as colony minimum dimension for data sampling.

Vegetation sampling

The vegetation sampling was conducted from March to July 2004 on 26 Cabrera vole colonies: five in Grândola, Cabrela, Ciborro and Alandroal, and six colonies in Mora. Road verge colonies (n=13) were considered when at distances of less than 30 m from a paved road, while meadow colonies (n=13) were considered when distances were more than 80 m, including meadows and other vegetation communities. Verge colonies included 12 secondary paved roads with low traffic volume, and only one national paved road with high traffic volume.

Two complementary methods were used to survey the vegetation in each colony. The composition and cover of tree and shrub strata were determined by searching for every species growing in each colony. The tree stratum included all woody species higher than 3 m; the shrub stratum thus corresponded to all woody species under 3 m in height (Humphries *et al.* 1996). Cover and height of woody species in the tree and shrub strata were calculated by visual estimation and averaged to an overall percentage in the colony (Bullock 1996, Boutin *et al.* 2002). Herbaceous vegetation was surveyed in 1 × 1 m plots, by stratified random sampling (e.g. Sorrels and Glenn 1991, Kent and Coker 1992).

Colonies were stratified by differences in slopes, soil moisture, soil type or marked differences in vegetation (Elzinga *et al.* 1998). Three to six plots were distributed along each colony and per visit, according to number of strata defined and colony area (three/four plots if occupied areas were under 300 m^2, five plots for 300 to 600 m^2 areas, and six plots for occupied areas above 600 m^2) (Duffy and Meier 1995).

Cover and height of all herbaceous species were recorded within each plot. Total canopy cover percentages of the herbaceous vegetation and bare ground were assessed by eye (0-100%).

A total of 191 plots was sampled: 113 in a first visit round and 78 in a second one (to confirm some late flowering grasses).

Nomenclature of plant taxa followed *Nova Flora de Portugal* (Franco 1971, Franco 1984, Franco and Rocha-Afonso 1994, Franco and Rocha-Afonso 1998, Franco and Rocha-Afonso 2003). A few species (e.g. *Leontodon* spp. and *Carlina* spp.) were identified only to genus level, while others (e.g. *Poa* spp., *Vicia* spp., *Galium* spp.) were identified to species, but pooled after to genus level.

Species were divided into several categories including lifespan, Raunkiaer life-form (e.g. geophyte, hemicryptophyte, therophyte), moisture affinity, ruderality and nitrophily, according to *Nova Flora de Portugal* and Valdés *et al.* (1987), and Duarte *et al.* (2002) for moisture indicators.

Soil sampling was carried out at 15-20 cm depth in all colonies during August 2004 for obtention of soil texture (sand and clay content), pH, organic matter content and water retention capacity (field capacity). Analyses were carried out at the Soils Physics Laboratory of Phytotechny, Department of the University of Évora.

Each colony was characterized by 25 explanatory variables concerning topography, plant diversity, Raunkiaer life-forms, taxonomic groups, disturbance and soil properties (table 1).

Data analysis

Floristic composition matrices were built with herbaceous species data only, while shrub and tree data were considered in the analyses as explanatory variables.

For evaluation of dissimilarities in plant species composition between meadow and road verge colonies, data were subjected to multi-response permutation procedure (MRPP) which permutes the abundance of species between colony types and compares their Euclidean distances analogous to one-way analysis of variance (McCune and Mefford

1999, Muotka *et al.* 2002). Detrended correspondence analysis (DCA) was performed to evaluate grouping of the two colony types according to their floristic compositions (e.g. Jongman *et al.* 1995) with downweight of rare species (Cowlishaw and Davies 1997) and detrending by segments optins (Jongman *et al.* 1995).

Plant species characterising the road verge colonies and the meadow ones were determined by indicator species analysis (ISA, Dufrêne and Legendre 1997). This method combines information on species abundance and frequency in either verge or meadow colonies. It produces indicator values for each species in the groups. The indicator values range from zero (no indication) to 100 (perfect indication). Both MRPP and ISA methods are tested for statistical significance using a Monte Carlo test (499 permutations) (Dufrêne and Legendre 1997, McCune and Mefford 1999).

Explanatory variables were compared between the two types of colonies using the Mann-Whitney test (Zar 1999). Non-parametric tests were preferred because of small sample sizes.

A direct gradient analysis (CCA or Canonical Correspondence Analysis) was applied to the vegetation data and to the significant variables in the Mann-Whitney tests (with $P<0.05$). Variables with ecological relevance were also included in the analysis. Decision on the final number of variables to enter in the analysis depended on obtaining a compromise between high values of explained variance, and significance of both eigenvalues and explanatory correlations at the axes. This ordination method was used to evaluate the pattern of variation in plant composition in colonies that can be best explained by the explanatory variables (ter Braak 1986, Jongman *et al.* 1995) providing a summary of the species-variables relationships (Jongman *et al.* 1995). Parameters used to interpret these ordination results included the eigenvalues and intraset correlations (ter Braak 1986, Jongman *et al.* 1995). The Monte Carlo permutation procedure was used to investigate the statistical significance of ordination axes (499 permutations). Explanatory variables were standartized to zero mean and unit variance (ter Braak 1986).

Cover percentage of each plant species, in the herbaceous stratum, was used in both ordinations techniques without transformations (Moustafa and Zaghloul 1996).

PC-ORD version 4 (McCune and Mefford 1999) was used for MRPP, Species Indicator Analysis, DCA and CCA. CANOCO for Windows version 4.5 (ter Braak and Šmilauer 2002) was only used for DCA and CCA plots, once it allows the representation of binary environmental variables. SPSS 10.0 (SPSS Inc. 1999) was used for Mann-Whitney tests and other ordinary statistical analyses. Significance is reported at α=0.05 level, unless noted otherwise in the text.

RESULTS

Floristic composition differences

A total of 186 vascular plant species were registered in all colonies; 145 of these occurred in the road verges (3 trees, 18 shrubs and 124 herbs and grasses), while 144 species were present in meadow colonies (5 trees, 18 shrubs and 121 herbs and grasses). Fifty-six percent of the total number of plant species was common to both colony types (two trees, 12 shrubs and 90 herbs and grasses). A moderated number of species were exclusive to each of the two colony types: 22% of species (one tree, six shrubs and 34 herbs and grasses) for road verges and another 22% of species (two trees, six shrubs and 33 herbs and grasses) for meadow colonies.

The herbaceous floristic composition of the two colony types registered significant differences (MRPP test: T=-2.655, $P<0.05$).

The DCA ordination results are shown in figure 1. The eigenvalues were 0.448 in the first axis (horizontal) and 0.322 in the axis 2 (vertical). There was a clear tendency of road verge colonies to be positioned on the right side of the figure, while meadow ones were on the left side (axis 1). The second axis indicated a heterogeneity gradient.

Most of the colonies of different geographical areas were distributed over several plot quadrants (figure 1). Exception is made with Mora colonies, placed at the centre, that presented an intermediate floristic composition between the two type of colonies. On the other hand, meadow colonies M6 and A7 seemed to have road verge characteristic species, which placed them in the right side of the figure.

Results from Indicator Species Analysis (ISA) showed that road verge colonies were characterized by the indicator presence of *Convolvus arvensis*, *Cerastium glomeratum*, *Geranium molle*, *Sherardia arvensis*, *Parentucelia viscosa*, *Galactites tomentosa*, *Cynara humilis*, *Sonchus oleraceus*, *Andryala integrifolia*, *Gynandriris sisyrinchium*, *Bromus diandrus*, *Bromus madritensis* and *Holcus lanatus* (appendix 1). Of the 13 road verge indicator species ($P < 0.10$), seven have annual life cycles, five are ruderal and two are nitrophilous species. Also, only few of these species reached high cover values in road verges, such as *Bromus madritensis* (max=16%), *Bromus diandrus* (max=6%) and *Holcus lanatus* (max=10%).

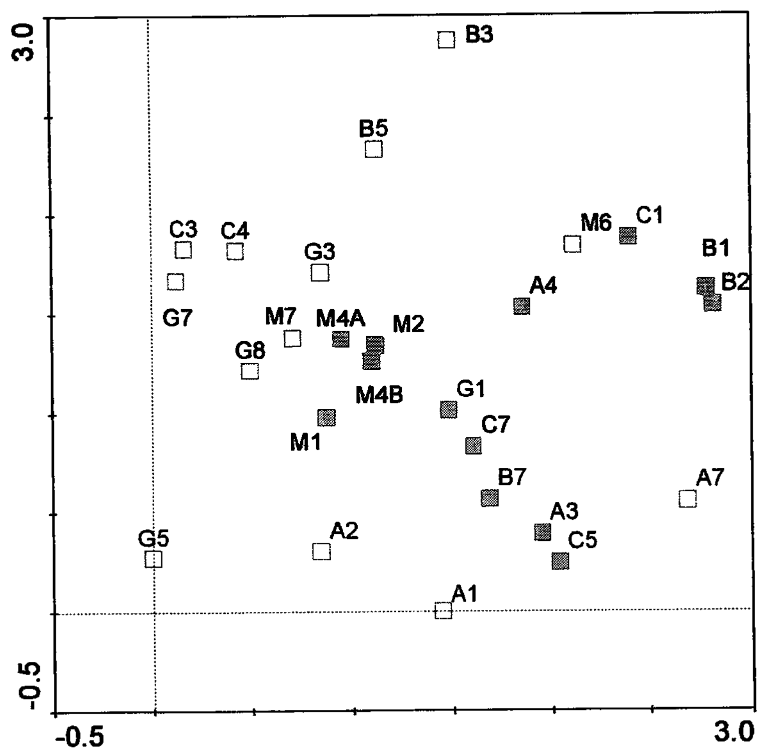

Figure 1. DCA plot ordination of 13 road verges and 13 meadows colonies, and 152 herbaceous plant species. The colony types are superimposed (full square: road verge colonies; empty square: meadow colonies); capital letters represent the five geographical areas (G: Grândola, B: Cabrela, C: Ciborro, M: Mora, A: Alandroal).

Other species like *Agrostis castellana, Festuca ampla, Holcus mollis, Scilla ramburei* and *Juncus acutiflorus* were ecological indicators of meadow colonies, albeit their indicator values were lower (appendix 1). Only the first two species were important in terms of cover area (> 10%), all five were perennial species and all indicate moisture conditions typical of meadows, excepting *A. castellana.*

On the other hand, there were frequent species (>1% cover) and common to both road verge and meadow colonies. These were *Geranium dissectum, Linum bienne, Plantago lagopus, Coleostephus myconis, Hedypnois cretica, Leotodon* spp., *Vulpia* spp., *Avena barbata, Bromus hordeaceus, Briza maxima, Cynodon dactylon, Lolium rigidum, Phalaris coerulescens, Holcus annuus, Dactylis glomerata, Carex* spp. and *Cyperus longus* (appendix 1).

Explanatory variables

Results of median comparisons between road verge and meadow colonies attributes are presented in table 1.

Table 1. List of 25 explanatory variables used in this study, median and range values in meadow and road verge colonies, and results of Mann-Whitney U tests ([a]Phy test for binary variables) and P-values.

Variables	Description	Meadow colonies	Road verge colonies	Univariate tests	P value
DIM	Colony dimension (m^2)	450 (200-2450)	240 (100-744)	**28.0**	**< 0.01**
WIDTH	Colony width (m)	14 (7-35)	4 (2-10)	**4.5**	**< 0.001**
ABUND	Vole abundance class (1-4)	3 (1-4)	2 (1-3)	70.0	ns
H'	Shannon's diversity measure	2.55 (1.47-3.15)	2.78 (2.01-3.22)	50.5	ns
EVEN	Evenness of H' diversity	0.68 (0.45-0.83)	0.74 (0.59-0.81)	58.0	ns
SG_m2	Number of grass species per m^2	2.2 (1.4-3.4)	3.75 (1.67-4.67)	**22.5**	**< 0.01**
BAR	Bare soil mean cover in the colony (%)	9 (3-16)	6 (4-16)	73.5	ns
TREE	Tree cover in the colony (%)	4 (0-15)	4 (0-70)	73.5	ns
SHRU	Shrub cover in the colony (%)	25 (10-60)	35 (1-60)	67.0	ns
MD_HH	Mean herbaceous height (m)	39 (32-48)	40 (32-56)	63.0	ns
RUDER	Proportion of ruderal species in the colony (%)	14.6 (6-22)	18.6 (14-29)	**44.5**	**< 0.05**
NITRO	Proportion of nitrophilous species in the colony (%)	3 (0-8)	7 (2-9)	**35.0**	**< 0.05**
MOIST	Proportion of moisture indicator species in the colony (%)	34 (15-50)	17 (12-38)	**33.0**	**< 0.01**
HMG	Hemicryptophyte or perennial grass cover (%)	42 (0-71)	22 (11-29)	**25.5**	**< 0.01**
TG	Therophyte or annual grass cover (%)	8 (1-28)	17 (2-53)	**43.0**	**< 0.05**
SHR_100	Number of shrub species per 100 m^2	1 (0-2)	2 (1-8)	**31.5**	**< 0.01**
S_RAUN	Number of Raunkiaer life-forms	8 (4-10)	9 (4-10)	75.5	ns
H_RAUN	Shannon's diversity of Raunkiaer life-forms	1.28 (0.8-2.0)	1.80 (1.0-2.0)	**40.0**	**< 0.05**
GRAZ	Presence of grazing signs inside the colony (0/1)	0 (0-1)	0 (0-0)	-0.426[a]	**< 0.05**
N	North exposure of the colony (0/1)	0 (0-1)	1 (0-1)	0.234[a]	ns
PH	Soil pH	5.8 (5.4-6.4)	5.8 (5.3-6.9)	73.0	ns
ORGM	Soil organic matter content (%)	2.4 (1-4)	1.8 (1-4)	66.0	ns
PF2	Soil water retention capacity at 2.54 pF (field capacity)	20 (6-35)	11 (8-31)	64.5	ns
SAND	Soil sand content (%)	46 (14-86)	69 (24-79)	67.0	ns
CLAY	Soil clay content (%)	17 (5-46)	18 (8-33)	84.0	ns

Colony dimensions were lower in road verges (240 m^2) than in meadow colonies (450 m^2; $P < 0.01$) and colony width was also lower in road verges (4 m) when compared with meadows (7 m; $P < 0.001$). Vole's abundance showed no significant differences. North exposure was not associated with colony types, but grazing was associated with meadow colonies (table 1).

In what concerns vegetation structure, no differences were registered for medians of tree, shrub and bare soil cover, and herbaceous vegetation mean height between the two colony types (table1).

Road verge colonies registered higher grass species richness per m^2 ($P<0.01$), higher diversity of shrub species per 100 m^2 ($P<0.01$) and higher diversity of Raunkiaer life-forms ($P<0.05$) when compared with meadow colonies. On the contrary, species diversity, species evenness and richness of Raunkiaer life-forms did not show any significant differences between the two types of colony (table 1).

Higher proportion of ruderal ($P<0.05$) and nitrophilous species ($P<0.05$) and lower proportion of moisture indicator species ($P<0.01$) were found in road verge colonies, as well as higher cover of annual grasses ($P<0.05$) and accordingly, lower cover values of perennial ones ($P<0.01$), when compared with meadow colonies (table 1).

Soil characteristics revealed no significant differences between colony types, namely pH, organic matter, field capacity and sand and clay content (table 1).

The direct gradient analysis (CCA) performed on 13 variables obtained eigenvalues of 0.448 ($P<0.01$) in the first axis and 0.382 in the second ($P<0.01$), both axes explaining 19.1% of the data variability (fig. 2, table 2). Values of correlation were 0.979 ($P<0.01$) for axis 1 and 0.955 (ns) for axis 2. First axis represented a gradient between the two colony types: meadows and road verges.

The CCA plot (fig. 2) showed that several variables were positively associated with road verge colonies (first axis): grass richness per m^2, annual grass cover, proportion of ruderal species and shrub richness, and negatively with perennial grass cover, proportion of moisture indicator species and colony width and dimensions. The second axis represented a gradient of shrub richness and sand content in the soil (positive side) and high proportion of ruderal species (negative side).

The observed eigenvalues in DCA and CCA were almost identical, which implies that the variables selected were good predictors of the compositional variation.

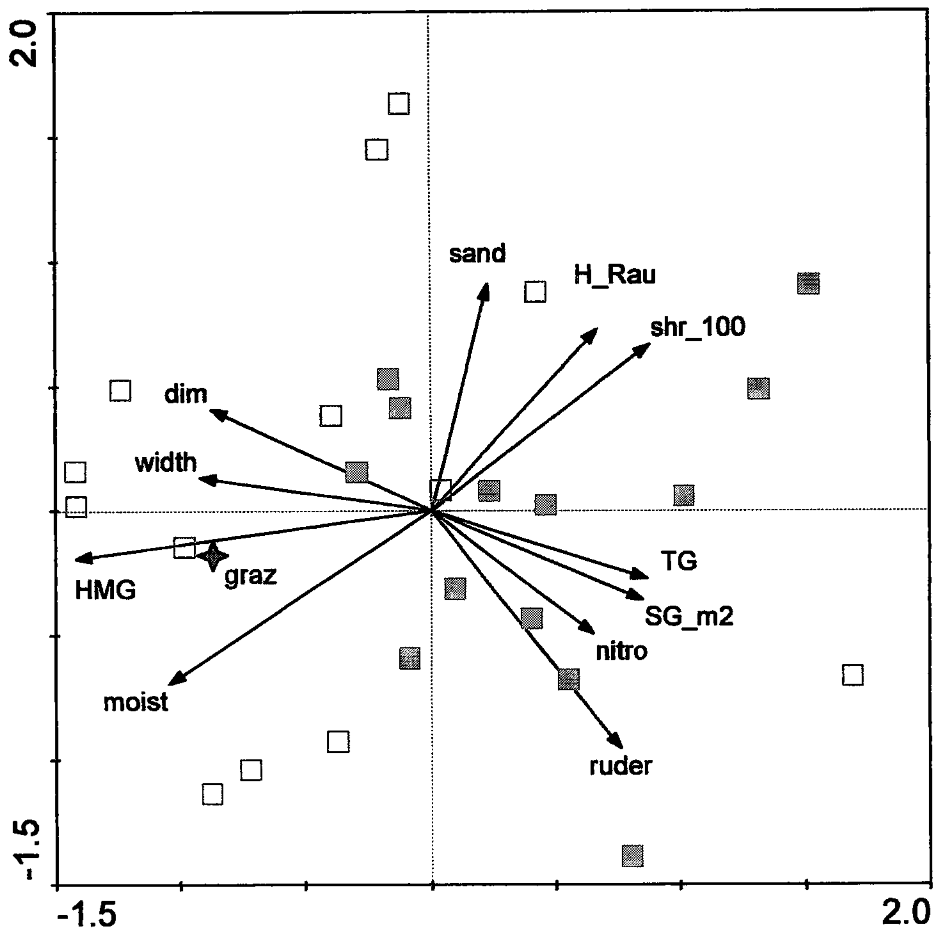

Figure 2. CCA ordination of 13 road verges and 13 meadows colonies, and 152 herbaceous plant species with 13 explanatory variables. Longer vector lines represent stronger "intraset correlations" (after ter Braak 1986). The colony types are superimposed (full square: road verge colonies; empty square: meadow colonies; full triangle: explanatory binary variable); (Explanatory variables as SG_m2: number of grass species per m^2; HMG: perennial grass cover; TG: annual grass cover; dim: colony dimension; shr_100: number of shrub species per 100 m^2; ruder: proportion of ruderal species in the colony; nitro: proportion of nitrophilous species in the colony; moist: proportion of moisture indicator species in the colony; H_Rau: Shannon's diversity of Raunkiaer groups; width: colony width; sand: sand content in the soil; graz: presence/absence of grazing signs).

Table 2. Correlations (*r*) between axes of species and explanatory variables from the canonical correspondence analysis (CCA) (intraset correlation) (VERGE: colony type; see table 1 for the other variables legend).

Variables	Axis 1	Axis 2
VERGE	-0.502	0.042
SG_m2	-0.535	0.149
HMG	0.835	0.166
TG	-0.514	0.166
DIM	0.549	-0.223
SHR_100	-0.508	-0.527
RUDER	-0.515	0.545
NITRO	-0.441	0.264
MOIST	0.583	0.471
H_RAU	-0.344	-0.493
WIDTH	0.655	-0.055
GRAZ	0.475	0.118
SAND	-0.051	-0.559

DISCUSSION

Road verge and meadow colonies of Cabrera vole had distinct herbaceous vegetation composition. Indicator species of road verge colonies corresponded mainly to annual grasses and forbs, ruderal and nitrophilous species. In meadows, perennial grasses and moisture indicative species were more common.

Road verge colonies showed higher cover values of annual grasses, ruderal and nitrophilous species, higher grass and shrub species richness, higher Raunkiaer life-forms diversity, lower cover of perennial grasses and low abundance of moisture indicator species. Other characteristics included lower colony dimensions and width, and grazing signs absence.

Overall, in the five geographical areas studied, both road verge and meadow colony types were found. Verges of Mora had intermediate floristic compositions which placed them in the centre of ordinations diagrams.

Some of the most frequent species in both colony types are common in the Cabrera vole's diet. These are *Vulpia* spp., *Agrostis castellana*, *Bromus* spp., *Briza maxima*, *Holcus lanatus* and *Avena barbata* (Soriguer and Amat 1988, Ayanz 1992, M. Costa *et al.*, submit.). Figure 3 shows the number of colonies where each of 18 species/genera referred as diet items occurred, and figure 4 shows the mean cover of the same taxa in the colonies. From the most consumed species group, *Agrostis castellana* was the only species with higher cover values in meadow colonies, all other five had higher cover in road verges, and are mainly annual species, excepting *Holcus lanatus*. Other consumed items include species common in road verges, but more abundant in meadows (*Phalaris* sp. and *Scorpiurus* sp.). In road verge colonies, the six most consumed and referred plant species were common (n ≥ 7 colonies) and abundant (1.5% to 10% cover). Occasionally, less common species (*Brachypodium phoenicoides*, *Poa* spp., *Scirpoides* sp., *Phalaris* sp.) reached almost 5% cover inside road verge colonies (figures 3 and 4). Meadow colonies had also high frequence of six of the most consumed species, but their abundance was under 3% cover, except for *A. castellana* which reached values of 22% cover. Other species, like *Phalaris* sp., *Scirpoides* sp. and *B. phoenicoides* had more than 5% cover in these colonies (figures 3 and 4). Based on these comparisons, it seems that road verges do not presented serious limitations in terms of availability of diet items, during the study period. In fact, they showed higher diversity among the most consumed grasses. Disadvantages of road verge colonies should be more important in terms of other physical conditions, such as habitat disturbance, moisture availability during the dry season and habitat dimensions.

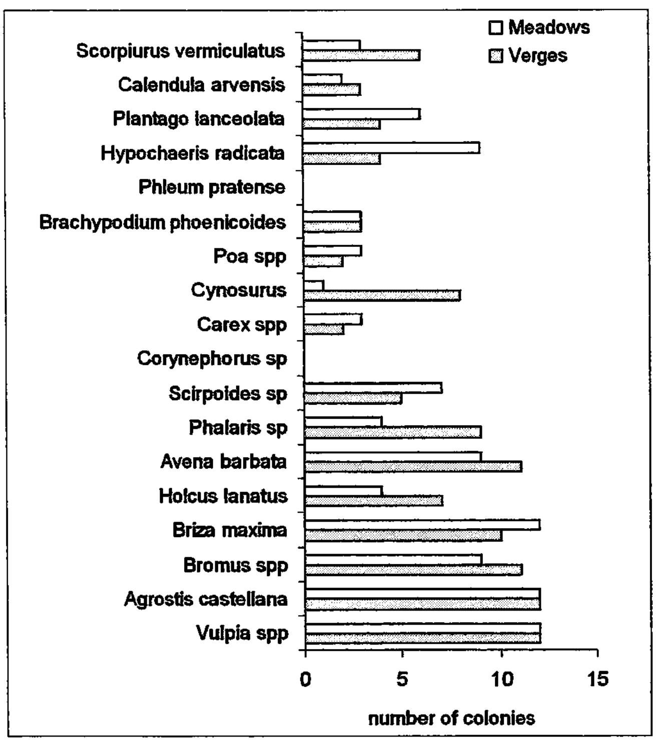

Figure 3. Frequence of occurrence in studied colonies of plant species referred as food items of Cabrera vole. *Vulpia* spp, *A. castellana*, *Bromus* spp., *B. maxima*, *H. lanatus* and *A. barbata* are considered the most consumed species (Soriguer and Amat 1988, Ayanz 1992, M. Costa *et al.*, submit.).

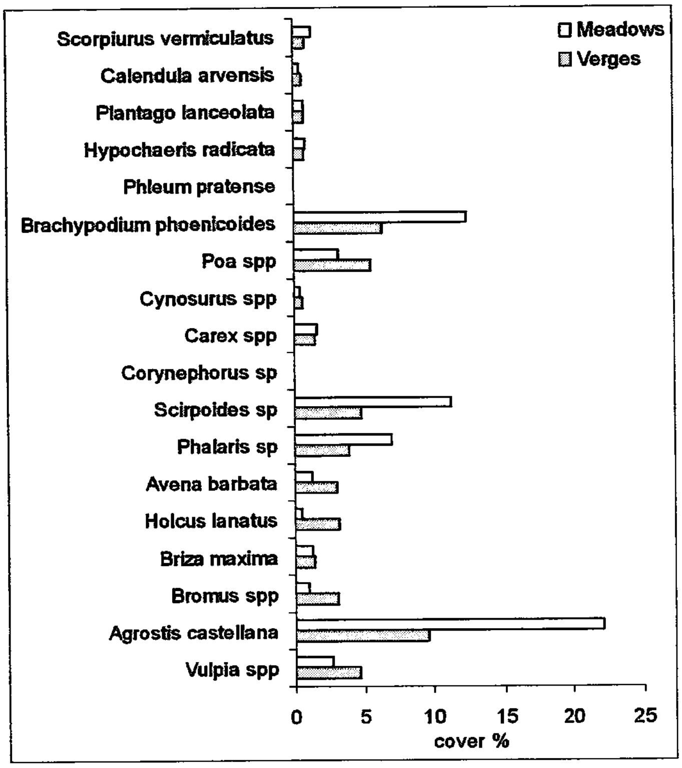

Figure 4. Mean cover percentage in studied colonies of plant species referred as food items of Cabrera vole. *Vulpia* spp, *A. castellana, Bromus* spp., *B. maxima*, H. *lanatus* and *A. barbata* are considered the most consumed species (Soriguer and Amat 1988, Ayanz 1992, M. Costa *et al.*, submit.).

High abundance of annual plants (short life cycles and dispersion by seeds) indicate high frequency of disturbance (Lavorel *et al.* 1997, Schweiger *et al.* 2000, Dupré and Diekmann 2001), while perennial grasslands are associated with low intensified and traditional agriculture landscapes and high habitat quality (Burel *et al.* 2004). Also, communities dominated by annuals and with low moisture conditions offer no guarantee of green food during the hot and dry Mediterranean summer. Although road verges can provide a high diversity of food items, their nutritional quality (protein, fiber and water content) should be lower when compared with meadow colonies. White *et al.* (2004) verified that, in low fertility soils, high grassland diversity was associated with low plant growth rates and low dry matter digestability, which is indicative of low food quality in road verges. Furthermore, during the summer, and when most annual grasses become senescent, protein content decline to 2-3% (Caughley and Sinclair 1994).

Most common interventions in the study areas and surroundings include high grazing pressure, land ploughing (e.g. Pinto-Correia and Mascarenhas 1999) and, specifically in road verges, mowing or ploughing works. In a recent work on plant diversity in road verges, it is concluded that road construction and maintenance activities (like vegetation removal) are the main factors controlling road verge communities composition (P.J. O'Farrell and S.J. Milton, in press). Several colonies of road verges (n=8) were delimited from adjacent areas by fences, which proved to be essential, in some cases, for the maintenance of adequate habitat structure for voles, like high herbaceous cover and height (e.g. Pita *et al.* 2003). In six of the "fenced" colonies, adjacent areas were overgrazed by cattle. These highlights one of the major adjavantages of verges in protecting the herbaceous vegetation communities from grazing (Burke *et al.* 2003, P.J. O'Farrell and S.J. Milton, in press), allowing the establishment of taller grasses (Bellamy *et al.* 2000). Although grazing presence was associated with meadow colonies at CCA ordination, the high cover of perennial species is typical of ungrazed grasslands (Noy-Meir *et al.* 1989). According to the low number of observed signs, grazing presence, during the studied period, was rare and occasional throughout the year. Grazing signs (mainly sheep) were detected only in four meadow colonies, in all geographical areas, except in Cabrela. Agriculture was only present in the immediate vicinity of two colonies (a rice field and a cereal crop).

High richness of shrubs and diversity of Raunkiaer life-forms in road verges were observed in some Cabrela and Ciborro colonies, more similar to a typical hedgerow structure and, although plowed/mowed, there was a shrub patch that remained and the colony persisted there. This persistence and developing of shrubs richness and Raunkiaer life-forms diversity is associated with lower disturbance frequency, due to verge topography or presence of a fence that constrained road maintenance works. This conclusion is suported by low abundance of annual grasses, and few ruderal or nitrophilous species in these colonies.

Main observed disturbance in road verge colonies was vegetation removal in the summer (verge clearing). Although executed only once a year, it happens when climatic conditions are less favourable for the Cabrera vole and changes drastically the habitat within seconds. If the entire colony was mowed, animals disapeared (one observation); if only a part or limit of the colony was destroyed, then animals could persist in the area (four observations).

Cabrera vole population mean density varies from 12 to 93 individuals per ha (Fernández-Salvador 1998). According to varying colony dimensions presented here (240 m^2 in road verges and 450 m^2 in meadow colonies), the corresponding number of individuals would range from 1 to 2 in smaller colonies and from 1 to 4 individuals in meadow colonies. In fact, live trapping data from Grândola area revealed numbers of 2 to 3 individuals per meadow type colony (Rosário *et al.* 2004). These numbers are typical of rare species occurring in fragmented areas, such as the *Microtus tatricus* of Carpathian Mountains with densities of 0.2 to 28.6 individuals per ha (Martínková and Dudich 2003).

Consequences of the smaller dimensions of road verge colonies should be a higher vulnerability of voles, due to lower number of individuals and stronger edge effect, leading to a higher local extinction risk, depending on the connectivity with other suitable patches (Bennett 1991, Saunders *et al.* 1991, Krohne 1997). Also, higher edge:area ratio could increase predation risk (Soulé and Gilpin 1991, Jacob and Hempel 2003). Bellamy *et al.* (2000) suggested that 4 m might be the minimum habitat width for *Microtus agrestis* in road verges. The range and median values observed in verges in the present study (2-10 m and 4 m, respectively), might indicate that minimum values for Cabrera vole can be slightly lower than suggested for *M. agrestis*. Indeed, a study on *Microtus pennsylvanicus* revealed that corridors with 1 m wide were enough for sink dispersion (La Polla and Barrett 1993). Moreover, there was no association between Cabrera vole abundance signs and colony width (Spearman correlation: r_s= -0.005, ns).

Other common small mammals are known to frequently use linear habitats, like *Clethrionomys glareolus* (Tattersall *et al.* 2002) or *Peromyscus leucopus* and *Microtus pennsylvanicus* (La Polla and Barrett 1993, Merriam and Lanoue 1990). The present study confirms also the importance of these habitats to the Cabrera vole, a threatened species. There is no information on whether road verges function as corridors or sink habitats for Cabrera vole. In either case, they should provide benefits such as extra foraging areas, refuges from adjacent disturbances and, in the case of corridor function, increase animal movements when searching for optimal habitats (Saunders *et al.* 1991, Soulé and Gilpin 1991, Szacki and Liro 1991, Lugo and Gucinski 2000).

CONCLUSIONS

According to Henle *et al.* (2004), the Cabrera vole holds some of the most important biological characteristics of a highly sensitive species to habitat fragmentation, namely, low natural abundance (Fernández-Salvador 1998, Mathias 1999), low reproductive potential (Fernández-Salvador *et al.* 2001), moderate or low dispersal ability and specialised habitat requirements (Fernández-Salvador 1998, Pita *et al.* 2003, S.M. Santos *et al.*, in press). Road verges may be a valuable refuge habitat when grazing and agriculture intensification don't allow the existence/persistence of meadows. These verges may also have an important role as dispersal corridors. However, habitat quality in the verges is lower and colony size is reduced. So, in areas of agriculture intensification, where fragmentation tends to be higher, areas for reestablishment through rehabilitation and revegetation of meadow colonies should be considered in species conservation planning. Future studies should focus on differences in fitness of individuals inhabiting these two habitat types, including rates of mortality related with road-killing.

ACKOWLEDGEMENTS

We are grateful to Carla Cruz for help in the botanical methods, Manuel João Pinto for valuable suggestions, Paulo Cardoso for helpful advise in data analyses, Inês Rosário for support and valuable discussions, and Rui Lourenço for support, encouragement, scientific discussions and help in the field work.

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Appendix 1. List of plant species identified inside road verge colonies and meadow colonies of Cabrera vole in southern of Portugal (freq: number of colonies with presence of each plant species, cover%: mean percentage of cover where it occurs, IV: Indicator value for each colony type and significance of Monte Carlo test: * P<0.05, ** P<0.01, *** P<0.001, nc: not calculated; ISA methodology applied only to herbaceous species; species occurring in less than three colonies were excluded from the list).

Road verge colonies	freq	cover %	IV	Meadow colonies	freq	cover %	IV
Agrostis castellana	12	9.64	0	*Agrostis castellana*	12	22.11	62.9*
Vulpia spp.	12	4.62	53.6	*Vulpia* spp.	12	2.71	0
Bromus madritensis	11	3.10	62.9*	*Briza maxima*	12	1.16	0
Avena barbata	11	2.98	57.9	*Tolpis barbata*	11	< 1	43.8
Leontodon spp.	11	2.48	51.1	*Leontodon* spp.	10	1.80	0
Medicago spp.	11	1.88	46.8	*Gaudinia fragilis*	10	< 1	0
Bromus hordeaceus	11	1.08	51.0	*Quercus suber*	9	6.92	nc
Sonchus oleraceus	11	1.02	76.1***	*Avena barbata*	9	1,21	0
Galactites tomentosa	11	< 1	62.8**	*Hypochaeris radicata*	9	< 1	38.2
Gaudinia fragilis	11	< 1	44.1	*Anagallis arvensis*	9	< 1	49.7
Vicia spp.	11	< 1	58.3	*Bromus hordeaceus*	9	< 1	0
Briza maxima	10	1.42	42.0	*Stachys arvensis*	8	< 1	0
Linum bienne	10	< 1	32	*Briza minor*	8	< 1	0
Geranium dissectum	10	< 1	31.2	*Galium* spp.	8	< 1	0
Andryala integrifolia	10	< 1	60.4**	*Rubus ulmifolius*	7	20.50	nc
Phalaris coerulescens	9	3.93	30.3	*Cistus salviifolius*	7	20.33	nc
Bromus diandrus	9	2.41	57.4**	*Scirpoides holoschoenus*	7	11.20	nc
Tolpis barbata	9	< 1	0	*Cynodon dactylon*	7	2.66	31.6
Galium spp.	9	< 1	60.0	*Mentha pulegium*	7	1.40	43.1
Cistus ladanifer	8	15.88	nc	*Linum bienne*	7	1.01	0
Sherardia arvensis	8	1.37	53.7*	*Daucus* spp.	7	< 1	0
Stachys arvensis	8	< 1	43.2	*Vicia* spp.	7	< 1	0
Cynosurus echinatus	8	< 1	38.3	*Festuca ampla*	6	60.70	41.9*
Sanguisorba minor	8	< 1	33.7	*Asphodelus* spp.	6	3.88	14.0
Briza minor	8	< 1	33.7	*Coleostephus myconis*	6	2.59	29.4
Quercus suber	7	19.00	nc	*Medicago* spp.	6	1.73	0
Holcus lanatus	7	3.21	49.0*	*Chamaemelum spp.*	6	1.50	35.1
Dittrichia viscosa	7	2.57	nc	*Geranium dissectum*	6	1,40	0
Asparagus aphyllus	7	1.86	nc	*Plantago lanceolata*	6	< 1	19.2
Cynodon dactylon	7	1.81	0	*Galactites tomentosa*	6	< 1	0
Brachypodium distachyon	7	< 1	22.9	*Crepis* spp.	6	< 1	24.4
Daucus spp.	7	< 1	32.2	*Dactylis glomerata*	5	2.02	0
Cerastium glomeratum	7	< 1	41.2*	*Lavandula luisieri*	5	1.67	nc
Quercus rotundifolia	6	10.30	nc	*Hypericum humifusum*	5	1.48	28.9
Dactylis glomerata	6	3.92	31.3	*Bromus madritensis*	5	1.20	0
Lavandula luisieri	6	3.50	nc	*Serapia lingua*	5	< 1	31.0
Asphodelus spp.	6	2.50	0	*Tuberaria guttata*	5	< 1	30.6
Scorpiurus vermiculatus	6	< 1	23.7	*Euphorbia* spp.	5	< 1	21.9
Chamaemelum spp.	6	< 1	0	*Sonchus oleraceus*	5	< 1	0
Rumex bucephalophorus	6	< 1	35.9	*Andryala integrifolia*	5	< 1	0
Senecio spp.	6	< 1	26.8	*Scilla ramburei*	5	< 1	38.5**
Crepis spp.	6	< 1	0	*Phalaris coerulescens*	4	7.01	0
Tuberaria guttata	6	< 1	0	*Cyperus longus*	4	5.01	22.7
Scirpoides holoschoenus	5	4.80	nc	*Dittrichia viscosa*	4	3.29	nc
Carlina spp.	5	2.11	0	*Ulex parviflorus*	4	3.00	nc
Echium plantagineum	5	1.41	31.7	*Carlina* spp.	4	2.86	17.8

Appendix 1. Continued.

Road verge colonies	freq	cover %	IV	Meadow colonies	freq	cover %	IV
Cynara humilis	5	< 1	37.1*	*Brachypodium distachyon*	4	< 1	0
Torilis spp.	5	< 1	38.5	*Rumex angiocarpus*	4	< 1	20.8
Convolvus arvensis	5	< 1	31.5*	*Asparagus aphyllus*	4	< 1	nc
Agrostis pourretii	5	< 1	23.9	*Holcus annuus*	4	< 1	0
Geranium molle	5	< 1	38.5**	*Holcus lanatus*	4	< 1	0
Anagallis arvensis	5	< 1	0	*Bromus diandrus*	4	< 1	0
Parentucelia viscosa	5	< 1	38.5**	*Sherardia arvensis*	4	< 1	0
Gynandriris sisyrinchium	5	< 1	38.5**	*Senecio* spp.	4	< 1	0
Holcus annuus	4	2.90	26.4	*Rumex bucephalophorus*	4	< 1	0
Coleostephus myconis	4	1.13	0	*Genista triacanthos*	4	< 1	nc
Trifolium angustifolium	4	< 1	21.8	*Holcus mollis*	4	< 1	30.8*
Bromus rigidus	4	< 1	19.7	*Juncus acutiflorus*	4	< 1	30.8*
Plantago lanceolata	4	< 1	0	*Brachypodium phoenicoides*	3	12.27	16.7
Hypochaeris radicata	4	< 1	0	*Poa* spp.	3	3.22	0
Lolium rigidum	4	< 1	0	*Daphne gnidium*	3	2.00	nc
Rumex angiocarpus	4	< 1	0	*Cistus ladanifer*	3	2.00	nc
Taeniatherum caput-medusae	4	< 1	30.8	*Scorpiurus vermiculatus*	3	1.25	0
Mentha pulegium	4	< 1	0	*Pulicaria paludosa*	3	< 1	0
Raphanus raphanistrum	4	< 1	16.4	*Ornithopus compressus*	3	< 1	17.8
Lathyrus angulatus	4	< 1	28.9	*Lotus* spp.	3	< 1	0
Cistus salviifolius	3	8.00	nc	*Trifolium angustifolium*	3	< 1	0
Brachypodium phoenicoides	3	6.29	0	*Sanguisorba minor*	3	< 1	0
Ulex parviflorus	3	5.00	nc	*Agrostis pourretii*	3	< 1	0
Plantago lagopus	3	4.58	18.4	*Carex* spp.	3	1.58	0
Bromus tectorum	3	3.39	23.1				
Hedypnois cretica	3	2.33	11.3				
Myrtus communis	3	1.67	nc				
Lotus spp.	3	1.03	18.3				
Silene gallica	3	< 1	15.7				
Calendula arvensis	3	< 1	13.6				
Aristolochia arvensis	3	< 1	20.4				
Euphorbia spp.	3	< 1	0				
Ornithopus compressus	3	< 1	0				
Serapias lingua	3	< 1	0				
Campanula lusitanica	3	< 1	14				

4. CONSIDERAÇÕES FINAIS

A análise da vegetação

As 26 colónias de rato de Cabrera seleccionadas no presente trabalho, estavam distribuídas por Grândola (5), Cabrela (5), Ciborro (5), Mora (6) e Alandroal (5).

A vegetação mais comum nas colónias era estruturalmente constituída por um estrato herbáceo acompanhado de arbustos isolados e de pequeno porte, ou um grupo de arbustos centrais de grandes dimensões, mais frequentemente com *Scirpoides holoschoenus*, *Cistus ladanifer*, *Dittrichia viscosa* ou *Lavandula luisieri*.

As espécies vegetais mais frequentes nas colónias foram: *Agrostis castellana* (92%), *Briza maxima* (85%), *Vulpia myuros* (85%), *Gaudinia fragilis* (81%), *Leontodon* spp. (81%), *Avena barbata* (77%), *Bromus hordeaceus* (77%) e *Tolpis barbata* (77%).

As colónias foram classificadas em oito grupos de comunidades vegetais que incluíram prados sub-húmidos, arrelvados de gramíneas altas e perenes, prados intervencionados, arrelvados dominados por espécies anuais, e comunidades herbáceas dominadas por espécies anuais, ruderais e nitrófilas.

Os principais gradientes relacionados com as diferenças florísticas encontradas referem-se à riqueza específica de gramíneas, à cobertura de gramíneas anuais e perenes, à cobertura de árvores, ao pH do solo, às dimensões das colónias, à abundância de espécies indicadoras de condições de humidade, à distância até à estrada de alcatrão mais próxima, à presença de indícios de pastoreio, à capacidade de campo e textura do solo, à abundância de espécies ruderais e à altura da vegetação herbácea.

Os prados sub-húmidos e os arrelvados de gramíneas altas e perenes mostraram oferecer melhores garantias em termos de qualidade de habitat: maior dimensão das colónias, menor perturbação do coberto vegetal e maior disponibilidade de gramíneas verdes durante o Verão. Estas características, por sua vez, relacionaram-se com maiores coberturas de gramíneas perenes, distância à estrada e presença de indícios de pastoreio e, por outro lado, com menor altura do estrato herbáceo, cobertura de gramíneas anuais, riqueza específica de gramíneas, número de espécies ruderais e pH do solo. As comunidades vegetais que sugerem melhores condições de habitat, são reconhecidas pela presença de *Agrostis castellana*, *Festuca ampla*, *Brachypodium phoenicoides*, *Phalaris* *coerulescens* e *Holcus lanatus* como espécies indicadoras e, na maioria das vezes, também como espécies dominantes.

Os resultados obtidos indicam que o rato de Cabrera consegue explorar uma considerável amplitude ecológica, dentro do que é a tipologia "prados e arrelvados de gramíneas densas e altas". Esta variabilidade de locais ocupados inclui comunidades pouco intervencionadas e com características de maior estabilidade (prados e arrelvados de gramíneas altas e perenes) e comunidades com indícios de intervenções frequentes e bermas de caminhos ou sebes (arrelvados e comunidades dominados por espécies anuais, ruderais e nitrófilas). As intervenções mais frequentes nas colónias são a remoção de arbustos com lavra e o corte da vegetação. Estas acções levam, muitas vezes, ao desaparecimento das colónias, quer por morte dos animais, quer por abandono dos locais.

Verificou-se, numa elevada percentagem de colónias, a presença vestigial de charcos mediterrânicos temporários, um habitat prioritário da Directiva de Habitats (Comissão Europeia 1999), o que sugere maiores condições de humidade nos locais ocupados, em relação às áreas envolventes. Uma das características dos microtídeos herbívoros é terem desenvolvido adaptações para uma dieta baseada em herbáceas, principalmente gramíneas, com uma distribuição normalmente restrita a áreas com permanência contínua deste tipo de vegetação, sendo um grupo quase ausente nos ambientes mais desérticos (MacArthur 1972).

<u>As colónias de berma de estrada</u>

Os resultados obtidos na segunda parte deste estudo indicam que a composição florística das colónias de berma é diferente da composição das colónias de prado. As espécies indicadoras das bermas correspondem essencialmente a gramíneas (*Bromus diandrus*, *Bromus madritensis* e *Holcus lanatus*), herbáceas anuais e espécies ruderais e nitrófilas (*Convolvus arvensis*, *Cerastium glomeratum*, *Geranium molle*, *Sherardia arvensis*, *Parentucelia viscosa*, *Galactites tomentosa*), acompanhadas por algumas herbáceas perenes (,*Cynara humilis*, *Sonchus oleraceus*, *Andryala integrifolia*, *Gynandriris sisyrinchium*,). Nas colónias de prado, predominam as gramíneas perenes e espécies indicadoras de condições de humidade e/ou encharcamento (*Agrostis castellana*, *Festuca ampla*, *Holcus mollis*, *Scilla ramburei* e *Juncus acutiflorus*).

As principais características associadas às colónias de berma de estrada são uma maior cobertura de gramíneas anuais, espécies ruderais e nitrófilas, maior riqueza específica de gramíneas e arbustos, maior riqueza de grupos fisionómicos de Raunkiaer, menores coberturas de gramíneas perenes e menor abundância de espécies indicadoras de humidade. Adicionalmente, este tipo de colónias tem menor dimensão e largura, assim como ausência de indícios de pastoreio.

Embora as bermas de estrada tenham uma maior diversidade de gramíneas, que poderão ser potencialmente consumidas pelo rato de Cabrera, as comunidades vegetais que lhe estão associadas apresentam algumas desvantagens, tais como menor estabilidade do habitat (devido à dominância de espécies de reduzida longevidade), menor disponibilidade de humidade durante o Verão e menor dimensão das colónias.

Este trabalho veio demonstrar que as bermas de estrada são um habitat frequente para o rato de Cabrera e discutir potenciais funções de corredores ecológicos.

Implicações para a conservação do rato de Cabrera

O rato de Cabrera ocorre em diversas tipologias de prados e arrelvados, com diferentes composições florísticas, condições de humidade, propriedades do solo e grau de perturbação do meio. Este tipo de informação fornece indicações importantes acerca da variabilidade dos habitats ocupados pela espécie, no sul de Portugal.

Tendo em conta que os arrelvados e comunidades dominadas por espécies anuais constituem habitats sub-óptimos para o rato de Cabrera, a verificar-se um aumento do número de colónias nestes locais, este facto poderá representar uma preocupação acrescida na conservação da espécie. Em regiões do país de maior intensificação agrícola, de elevada densidade de cabeças de gado, ou de produção florestal em grandes monoculturas, o habitat "de berma" (sebes, cercas, margens de campos agrícolas) poderá ser o único disponível para a espécie. De qualquer modo, é necessário o estudo comparativo das consequências resultantes da ocupação de colónias em prado ou arrelvados perenes e de colónias em arrelvados anuais ou comunidades de berma de estrada, em termos de "fitness" dos indivíduos (abundância, taxas de sobrevivência, parâmetros reprodutores).

O rato de Cabrera tem algumas características que o tornam particularmente sensível à fragmentação do habitat e à ocorrência de extinções locais, tais como: abundâncias reduzidas (Fernández-Salvador 1998, Mathias 1999), baixo potencial reprodutor (Fernández-Salvador *et al.* 2001), média ou reduzida capacidade de dispersão e requisitos ambientais estreitos (Fernández-Salvador 1998, Pita *et al.* 2003, Santos *et al.* em publicação) (Henle *et al.* 2004).

As colónias de berma de estrada têm, regra geral, menores dimensões. Esta característica poderá aumentar a vulnerabilidade dos animais, devido ao menor número de indivíduos que estas áreas poderão albergar, ao maior efeito de orla, ao maior risco de extinção local (dependente do grau de conectividade entre locais adequados) (Saunders *et al.* 1991, Krohne 1997), implicando, consequentemente, um maior risco de consaguinidade (Simberloff & Cox 1987). Adicionalmente, elevados quocientes de perímetro de orla / área interior poderão aumentar o risco de predação destes animais (Soulé & Gilpin 1991, Jacob & Hempel 2003), conduzindo, assim, a extinções locais.

O presente estudo demonstrou, apesar de algumas desvantagens, a importância das bermas de estrada como habitat para este mamífero ameaçado. Até ao momento, não existem dados concretos sobre a função destas bermas para a espécie. Poderão funcionar como corredores ecológicos ou "sumidouros" (habitats de recepção de imigrantes), num contexto de dinâmica de metapopulações (Bennett 1990, Hanski 2001). Em qualquer dos casos, este habitat poderá oferecer diversas vantagens, tais como áreas de alimentação extra, protecção de intervenções frequentes na vegetação e, no caso da função de corredor de ligação, potenciar movimentos de animais entre áreas de habitat mais favorável, como as "colónias de prado" (Saunders *et al.* 1991, Soulé & Gilpin 1991, Szacki & Liro 1991, Lugo & Gucinski 2000).

Prevê-se a aplicação dos resultados de análise geral da vegetação em situações de âmbito regional, onde se pretenda seleccionar área prioritárias dirigidas exclusivamente, ou não, ao rato de Cabrera. O estudo da vegetação das colónias permitiu concluir que determinadas composições florísticas poderão ser mais favoráveis à permanência, a longo prazo, dos animais em determinados locais, frequentemente de dimensões reduzidas e com indícios de alagamento temporário durante o Inverno/Primavera. Na referida selecção de áreas, deverá ser dada preferência a opções que potenciem o movimento de animais entre diferentes colónias. Embora os dados aqui apresentados não permitam concluir que as bermas de estrada funcionem como corredores ecológicos, a sua abundância numa área de ocorrência de colónias poderá ser benéfica para a espécie.

Em regiões do país com usos agrícolas ou pecuários mais intensivos, e onde a fragmentação de colónias poderá ser mais elevada, a recuperação de prados e arrelvados deverá ser considerada em acções de conservação dirigidas a esta espécie. No entanto, a recuperação ou criação de corredores de gramíneas altas e de elevada cobertura poderá aumentar a mobilidade dos animais e facilitar a ocupação de locais mais favoráveis, como os prados e arrelvados.

Por outro lado, é interessante o registo da espécie associado à presença de charcos mediterrânicos temporários, o que sugere uma associação de elevado valor para a conservação e pode constituir uma ferramenta útil na identificação de novas colónias e na sua conservação.

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