Hystrix It. J. Mamm. 19(2) 2008: 121-131

A REVISION OF THE DISTRIBUTION OF CABRERA'S VOLE *(MICROTUS CABRERAE* THOMAS 1906) IN ANDALUSIA (SOUTHERN SPAIN)

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Received 29 August 2008; accepted 12 November 2008

ABSTRACT - This paper consists of a revision of existing records of Cabrera's Vole *Microtus cabrerae* in Andalusia (southern Spain) and provides new data from a survey of both previously investigated and new areas. Cabrera's voles were found at only three of the 17 previously known localities, whilst the species may in fact be extinct in 12 localities. Our results suggest that the species could have disappeared from the central part of the province of Granada. Nevertheless, fieldwork revealed 138 new localities in 24 UTM 10x10 km squares scattered throughout the Cazorla-Segura Mountains and the extreme north of the provinces of Almería and Granada. In 13 of these squares, the presence of the species was confirmed by the capture of 16 specimens. Despite the new localities discovered, the species should still be considered as 'Critically Endangered' in Andalusia.

Key words: *Microtus cabrerae*, threatened species, distribution, conservation, Spain

RIASSUNTO – ***Revisione della distribuzione dell'arvicola di Cabrera (*Microtus cabrerae *Thomas 1906) in Andalusia (Spagna meridionale).*** Il presente articolo consiste di una revisione dei dati disponibili sull'arvicola di Cabrera *Microtus cabrerae* in Andalusia (Spagna meridionale) e fornisce dati originali ottenuti tramite un'indagine svolta sia in aree già investigate, sia in aree mai monitorate in precedenza. L'arvicola di Cabrera è stata individuata solo in 3 delle 17 località segnalate in letteratura, mentre in 12 di esse potrebbe essere estinta. I risultati ottenuti suggeriscono che la specie sia attualmente scomparsa dalla porzione centrale della provincia di Granada. Tuttavia, le indagini hanno permesso di rilevare la presenza della specie in 138 nuove località distribuite in 24 quadrati UTM 10 x 10 km corrispondenti alla catena montuosa di Cazorla-Segura e all'estrema parte settentrionale delle province di Almeria e Granada. In 13 quadrati la presenza è stata confermata tramite la cattura di 16 individui. Nonostante la scoperta di questi nuovi nuclei, la specie deve essere tuttora considerata "in pericolo critico" in Andalusia.

Parole chiave: *Microtus cabrerae*, specie minacciate, distribuzione, conservazione, Spagna

INTRODUCTION

The characterisation of the distribution and demography of threatened species is a vital step towards both the knowledge of their conservation status and the implementation of strategies aimed at preventing their extinction by means of the application of sound conservation measures within the correct geographical framework (Colwell and Coddington, 1994; Williams *et al*., 1996; Barea-Azcón *et al*., 2006).

This is the case of Cabrera's vole, catalogued in Andalusia as 'Critically Endangered', a species for which few distribution data are available (Franco and Rodríguez, 2001). In an attempt to alleviate this dearth of information, the Doñana Biological Station (CSIC) signed collaboration agreements with the Spanish Autonomous National Park Authority in 2004 and 2005 [Status and Distribution of the Snow vole (*Chionomys nivalis*) and Cabrera's vole (*Microtus cabrerae*) in the Sierra Nevada National Park] and the Environment Department of the Andalusian Autonomous Government (Consejería de Medio Ambiente de la Junta de Andalucía) in 2006 and 2007 [Bases for a Recovery Plan for Cabrera's vole (*Microtus cabrerae*) in Andalusia].

The main aim of these two projects was to locate the populations of Cabrera's Vole in Andalusia as a first step towards the implementation of effective conservation measures. This article summarizes the main results from these two studies and represents a significant advance in the knowledge on this vole in Andalusia.

STUDY AREA

Andalusia is located on the Southern edge of Spain, around the East-West axis formed by the valley of the River Guadalquivir. This river rises in the eastern half of the Betic mountain range, whose core is formed by the metamorphic mountains of Filabres and Sierra Nevada (3482 m), surrounded by alluvial-lacustrine basins (Guadix-Baza and Granada) and dolomite and limestone mountains (Harana, Baza, Mágina, Cazorla-Segura and Subbetic of Córdoba) (Fig. 1). Moreover, on the northern side of the river there are the metamorphic and plutonic hills of Sierra Morena. The region shows a Mediterranean climate, characterized by hot-dry summers and cold-humid winters, but with a high variability due to the rough orography: humid climates in Cazorla-Segura and Sierra Nevada mountains or semi-arid conditions in the coastal plains of Almeria and the Guadix-Baza basins. However, the studied area is crossed by alluvial and marly valleys, which are mostly cultivated, even if they conserve on marginal areas some natural hygrophilous ecosystems providing stable moist conditions.

METHODS

In order to draw an exhaustive picture of the distribution of Cabrera's vole two complementary areas of research were undertaken: (a) all available bibliographical information on the species in Andalusia, ranging from paleontological and archaeological information to data on its current status, was collated; (b), field work was carried out at known localities for the species, to verify its current status, as well as in suitable areas previously not investigated, in an attempt to find new population nuclei.

In particular, surveying was carried out in those UTM 10x10 km squares fulfilling the following prerequisites:

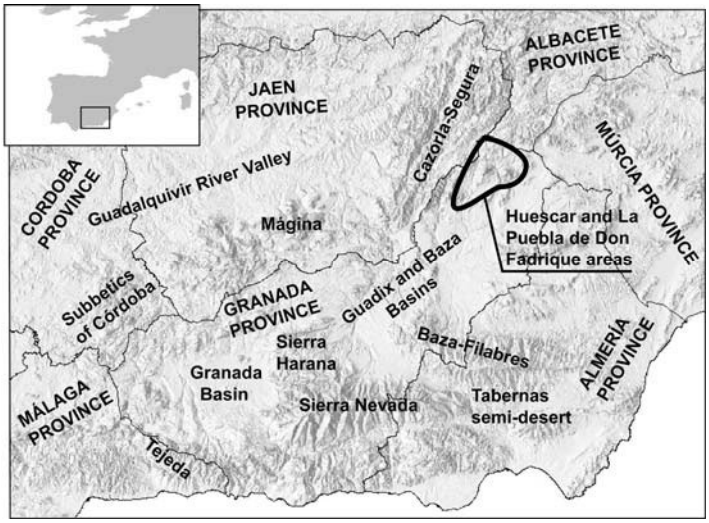

Figure 1 - Study area.

a) squares for which previous records were available, b) squares contiguous to those with previous records, c) squares including well preserved ecosystems which might be suitable for the species according to its habitat requirements (e.g. hygrophilous pastures, reed- and rush-beds and mixed formations; San Miguel Ayanz, 1992 and 1994; Fernández-Salvador, 1998 and 2002; Landete- Castillejos *et al*., 2000; Soriguer and Palomo, 2001).

These squares were identified through the analysis of the Autonomous Government's digital aerial photographs (colour series 1998-1999).

The selected sites for each UTM square were searched for signs of presence of Cabrera's vole, such as faeces and runs and, to a lesser extent, burrows, above-ground nests and food remains (Fernández-Salvador, in press; San Miguel Ayanz, 1992; Fernández-Salvador, 2002). The traces left by this species can be confused in the study area with those of the Southern water vole (*Arvicola sapidus* Miller, 1908) (Román, 2003) and, in the case of runs and burrows, with those of the Mediterranean pine vole (*Microtus duodecimcostatus* De Sélys-Lonchamps, 1839).

A personal reference collection of faeces from captive individuals of the three vole species helped their field identification, as did the analysis of the specific characteristics of the burrows and runs of the Mediterranean pine vole in the Sierra Nevada.

For each selected sampling locality, ground vegetation was examined until the first clear evidence of the species was found or the search had covered between 50 and 100 % of each suitable habitat. Those sites for which the presence of the species had been recorded in the past, as well as neighbouring areas, were searched thoroughly to avoid false negatives.

For a sample of 1-4 localities with definite traces in each UTM positive square, a total of 10-15 Sherman traps were laid down, along runs or around latrines (Delany, 1981; Gurnell and Flowerdew, 1982) to test and confirm the presence of the species (Landete-Castillejos *et al*., 2000). Traps were left active for a maximum of four nights and were checked at least twice a day. They were completely removed from

each square after the first successful capture.

Captured voles were identified by their general aspect, the relative length of head and body vs. tail, the number of foot pads and the length of their back feet (Castells and Mayo, 1993; Moreno and Balbontín, 1998; Fernández-Salvador, 1998 and 2002). After having taken a sample from the tip of the tail and collected all ectoparasites, all voles were released at the site of capture.

Sampling sites were georeferenced with an Etrex Garmin GPS (12 channels) configured for European Datum 1979, zone 30N Iberian Peninsula. Data were stored in an apposite database using Access, whilst spatial analyses were carried out using Arcview GIS 3.2 and ARCGIS 9.

As a protection measure, the exact coordinates of the positive sites can be consulted in Garrido-García *et al.* (2007) if prior permission has been obtained from the Environment Department of the Andalusian Autonomous Government.

RESULTS

1. Revision of previous data

In Andalusia, Cabrera's vole has been recorded in deposits from the Upper Pleistocene at Cueva Pastora, Cueva de la Carihuela, Yedras and Cueva Horá (Granada), Serra-1 (Almería) and Boquete de Zafarraya (Málaga), and from Neolithic and/or Copper and Bronze Ages at Castellón Alto (Granada) and Cueva de Nerja (Málaga) (Ruiz Bustos and García Sánchez, 1977; Ruiz Bustos, 1978; Barroso *et al.*, 1984; Sevilla, 1988; Vega Toscano *et al.*, 1989; Morales Muñiz, 1990; Delgado Castilla *et al*., 1993; Ruiz Bustos, 1995; Arribas, 2004; Aguayo de Hoyos *et al.*, in press).

The first modern records are from the Cazorla-Segura Mountains (Niethammer *et al.*, 1964; Otero *et al*., 1978). Subsequently, San Miguel Ayanz (1992) located other sites in the same mountain range and in Huescar (Granada), while Garrido-García (1999) and Garrido and Nogueras (2002-2003) found the species in the Guadix Basin and the mountains of Baza and Harana (Granada); a wrong UTM reference was assigned to the latter records, although true locations had been used (Garrido-García, pers. comm.).

The skin and skeleton of a vole captured in Laguna de Valdeazores (Jaén) on 10 April 1980 are preserved in the National Natural History Museum in Madrid (MNCN 12825, MNCN 11432) (Blanca Ramos, pers. comm., 2007).

All the above-cited records, as well as others whose origin remains unclear, are included in the distribution map by Fernández-Salvador (2002).

A record from the Subbéticas Mountains consists of a cranium (possibly subfossil) found in the municipality of Carcabuey (Córdoba) (Soriguer and Palomo, 2001; Spanish Ministry of the Environment, 2006), although no other evidence of the presence of the species has been found in the area. The populations in the Sierra Nevada cited by Soriguer and Palomo (2001) almost certainly refer to the records in Garrido-García (1999) and Garrido and Nogueras (2002-2003).

Except for the data supplied by Niethammer *et al*. (1964), Otero *et al*. (1978), Soriguer and Palomo (2001) and the Spanish Ministry of the Environment (2006), for which no coordinates were available, all the above-cited records of the distribution of

Cabrera's vole corresponded to 23 UTM squares. All data have been carefully revised, splitting up the squares into the following two groups (Fig. 2):

- confirmed squares: 30SVG63, 30SVG93, 30SWG19, 30SWG39, 30SWH10, 30SWH24, 30SWH25, 30SWH31 and 30SWH34, reported in Fernández-Salvador (2002); 30SWH26, marked on the map in San Miguel Ayanz (1992); 30SVG83, 30SVG95, 30SWG03 and 30SWG012, unmarked on the map in Fernández- Salvador (2002), due to an error when assigning UTM coordinates to the sites found by Garrido-García (1999).
- refused squares: 30SWG09, 30SWH00, 30SWH42, 30SWH43 and 30SWH45, marked on the map in Fernández-Salvador (2002), for which we were unable to find the source for Andalusia; 30SWH44 which belongs to the province of Albacete in Castilla-La Mancha Region (Landete-Castillejos *et al*., 2000); 30SWH16, marked on the map in Fernández-Salvador (2002), which may refer to records that we were unaware of or to the erroneous assignation of a locality by San Miguel Ayanz (1992); 30SVG84 and 30SWG13, whose presence on the maps in Fernández-Salvador (2002) was due to the erroneous assignation of the sites found by Garrido-García (1999).

The 14 confirmed squares included 17

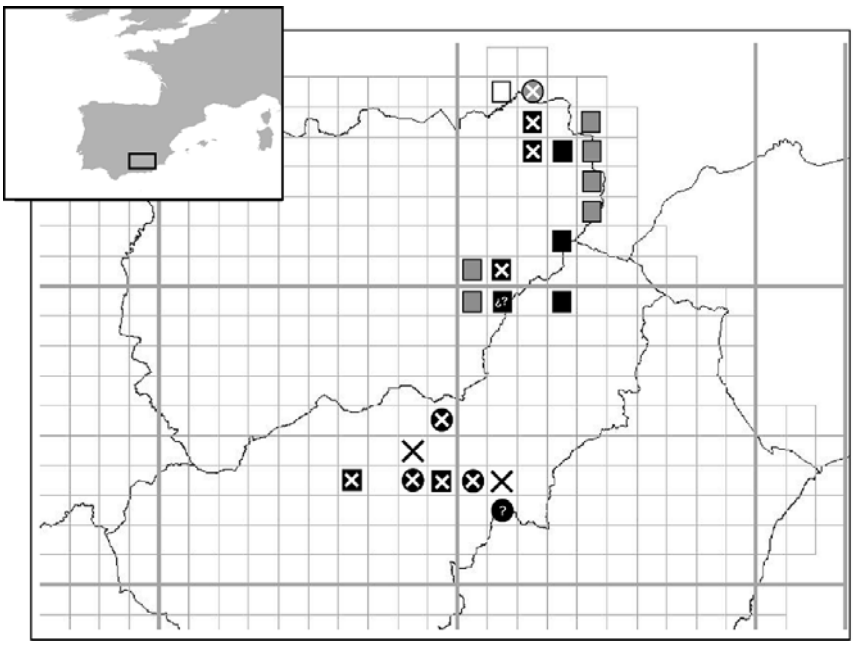

Figure 2 - Results of the revision of previous records: squares correspond to the UTM squares given by Fernández Salvador (2002), circles to data from other sources, 'X' to erroneous records. UTM squares with no known localities ("refused squares") are in white (possible error) or grey; black squares correspond to currently positive localities. A white 'X' indicates the possible species extinction in all known localities, '?' the finding of unconfirmed traces, and '¿?' a site that has not been visited.

localities, of which 16 were visited, providing definite evidence of the presence of the species in three squares (30SWG39, 30SWH31 and 30SWH34). A fourth square (30SWG12) remains doubtful, trapping having proved unsuccessful (Fig. 1).

Amongst the 12 localities in which no traces were found, 10 had been severely altered by overgrazing (5), road-widening (1), agriculture (3) or water extraction (1), which had resulted in the partial or total destruction of the habitats suitable for Cabrera's vole and the disappearance of its populations.

2. Field sampling

In all, 120 UTM 10x10 km squares were chosen (12,000 km^2, 13.8 % of the total surface of Andalusia). Apart from squares in the north-west of Huelva and south of Córdoba, all were in the provinces of Almería, Granada and Jaén (108 UTM squares, 90.1 %), above all in the centre and north of Granada and the mountains in the south and east of Jaén (Fig. 3). Within this area, 1,078 localities were visited: in 909 (84.4 %) cases no trace of Cabrera's vole was found, in 33 (3.1 %) cases traces could not be attributed with certainty to this vole and in 138 (12.8 %) cases runs and excrements belonging to the species in an area covering a total of 26.3 ha were found.

From the 171 sites where traces had been found, 27 were selected for trapping. In all, 266 micromammals belonging to six species were trapped (*Crocidura russula*, *Apodemus sylvaticus*, *Mus spretus, Mus domesticus, Microtus duodecimcostatus, Microtus cabrerae*), of which 16 (6.1%) corresponded to the target species (3 juvenile ♂♂, 1 adult ♂, 2 juvenile ♀♀, 7 adult ♀♀ and 3 juveniles whose sex could not be determined), captured at 13 different sites (Tab. 1).

Our overall data suggest that Cabrera's

Table 1 - Current distribution of Cabrera's vole in Andalusia. The first two columns refer to the revision of previous data, the column 'Trace' to the result of our field work (No = no traces; P = probable traces; S = definite traces), "Trapping" to the result of captures in sampling UTM squares. UTM squares in bold include the new localities where the species was recorded.

Square	Previous data	Revision of previous data	Traces			Localities with traps (individuals caught)	Presence of *M. cabrerae*
			No	P	S		
30SVF59	--	--	10	4	--		Unconfirmed
30SVF89	--	--	21	3	--		Unconfirmed
30SVG62	--	--	10	2	--		Unconfirmed
30SVG63	1	0	12	--	--		Extinct?
30SVG71	--	--	16	2	--		Unconfirmed
30SVG80	--	--	13	1	--		Unconfirmed
30SVG83	1	0	1	--	--		Extinct?
30SVG93	1	0	2	--	--		Extinct?
30SVG95	1	0	1	--	--		Extinct?
30SWG00	--	--	15	1	--		Unconfirmed

Tab. 1 - continues

Square	Previous data	Revision of previous data	Traces			Localities with traps (individuals caught)	Presence of *M. cabrerae*
			No	P	S		
30SWG03	1	0	5	1	--		Unconfirmed
30SWG09	¿?	0	19	--	1		**Sure (traces)**
30SWG12	1	1 (¿?)	1	2	--	1 (none)	Unconfirmed
30SWG19	1	0	18	--	1		**Sure (traces)**
30SWG22	--	--	5	5	--	3 (none)	Unconfirmed
30SWG29	--	--	8	--	2		**Sure (traces)**
30SWG38	--	--	3	--	1	1 (none)	**Sure (traces)**
30SWG39	1	1	13	--	26	2 (1 ♀ ad.)	**Sure (capture)**
30SWG49	--	--	11	3	16	2 (1 ♂ juv.)	**Sure (capture)**
30SWG77	--	--	2	--	7	1 (1 ♀ ad.)	**Sure (capture)**
30SWG78	--	--	2	--	5	1 (1 ♀ juv.)	**Sure (capture)**
30SWG87	--	--	1	--	2	1 (1♂ ad.)	**Sure (capture)**
30SWH00	¿?	0	12	--	--		Extinct?
30SWH10	1	0	9	--	--		Extinct?
30SWH16	¿?	0	5	--	--		Unconfirmed
30SWH22	--	--	1	--	1		**Sure (traces)**
30SWH24	1	0	25	--	4	1 (none)	**Sure (traces)**
30SWH25	2	0	69	--	11	5 (2 juv. and 2 ♀♀ ad.)	**Sure (capture)**
30SWH26	1	0	5	--	2	1 (1 ♀ ad.)	**Sure (capture)**
30SWH30	--	--	14	--	11	2 (1 ♀ juv.)	**Sure (capture)**
30SWH31	1	1	26	--	6	2 (1 ♀ juv.)	**Sure (capture)**
30SWH32	--	--	2	--	1	1 (none)	**Sure (traces)**
30SWH33	--	--	5	--	2	1 (none)	**Sure (traces)**
30SWH34	3	1	28	--	5	1 (1 ♀ juv.)	**Sure (capture)**
30SWH35	--	--	--	--	5	1 (none)	**Sure (traces)**
30SWH36	--	--	8	--	2	1 (1 juv.)	**Sure (capture)**
30SWH40	--	--	26	3	18	1 (1 ♀ ad.)	**Sure (capture)**
30SWH41	--	--	9	--	2	1 (1♂ juv.)	**Sure (capture)**
30SWH42	¿?	0	17	--	--		Albacete?
30SWH43	¿?	0	15	--	1		**Sure (traces)**
30SWH44	¿?	0	7	--	--		Albacete?
30SWH45	¿?	0	--	--	--		Albacete?
30SWH50	--	--	6	--	7		**Sure (traces)**

vole is currently found in Andalusia in 24 UTM 10x10 km squares, above all in the Cazorla-Segura Mountains and in the extreme north of the provinces of Granada and Almería. In 13 squares, the presence of the species was proven by captures, whilst in the other 11 squares traces provided indirect evidence of the species' presence. In nine squares in Sierra Nevada, Sierra Hara-

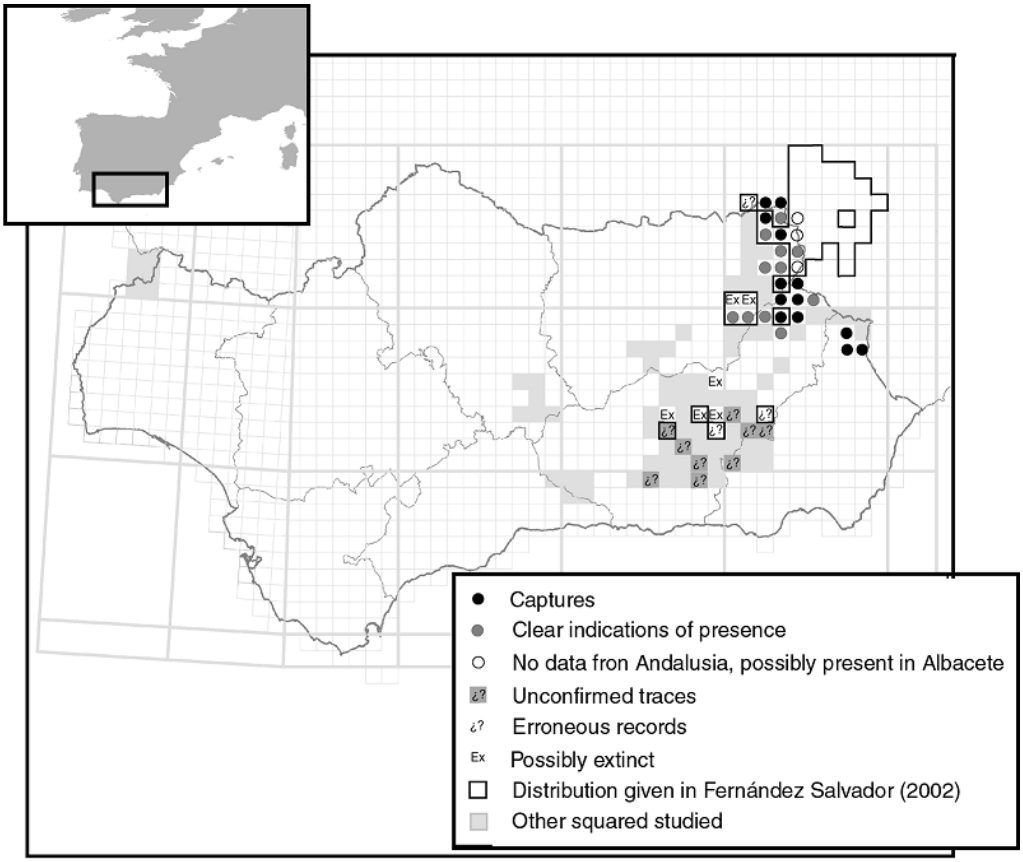

Figure 3 - Overall results of the survey carried out in Andalusia.

na and Sierras de Baza-Filabres evidence of the species' presence remains unconfirmed. Furthermore populations of the vole may still exist in three squares belonging to the province of Albacete (Castilla-La Mancha Region) (Fig. 3).

DISCUSSION

The distribution area of *M. cabrerae* has suffered a great reduction over the last 15,000 years as can be judged by the presence of the species in archaeological and paleontological records from the Upper Pleistocene and first half of the Holocene from areas that this vole no longer inhabits (Fernández-Salvador, 1998; López- Martínez, 2003; Arribas, 2004). This phenomenon has also occurred on a more local scale and remains of the species have been found in Andalusia (Sierras de Tejeda- Almijara, Tabernas semi-desert) far from its current areas of distribution.

The current species' range in Andalusia was confirmed to be restricted to the north-east of the region. Nonetheless, our data provided information at a

more detailed scale. The species' distribution was thought to be centred on the mountains of Cazorla-Segura, with marginal populations in the province of Granada. Although the presence of the species in these mountains has been confirmed (upper reaches of the Guadalquivir valley) and shown to be wider than previously realised, the centre of the species' range seems to lie in the municipalities of Huescar and La Puebla de Don Fadrique in Granada (85 sites, 61.6 % of records for the region) and includes also the extreme north of the province of Almería.

Our results suggest that Cabrera's vole populations in the southern half of the Cazorla-Segura Mountains - where the species may be extinct in two UTM 10x10 km and where we only found evidence of seven populations - are seriously threatened. Furthermore, the panorama is even bleaker in the centre of Granada province, where all known populations have disappeared, although a few as yet unconfirmed populations may survive in Sierra Nevada and Sierra de Baza-Filabres. Available information on extinct populations is too patchy to be used to show tendencies that can be extrapolated to the rest of the region, although it is clear that overgrazing, the ploughing up of pastures for tree plantations, road improvements and water capture are some of the main threats to the survival of the species (Soriguer and Palomo, 2001; Fernández-Salvador, 2002).

The overall area occupied by Cabrera's vole in Andalusia is very small (26.3 ha) and the comparison with previous data suggest that the species is undergoing a continuous decline as a consequence of the destruction of suitable habitats. Using the IUCN criteria (1999, 2003), the species should be classified as 'Critically Endangered' (criteria B1 and B2 a, b, c and d), as already proposed by Soriguer and Palomo (2001).

Our study has increased the amount of data available on the distribution and ecology of Cabrera's vole and provides the bases for the drawing up and execution of a recovery plan for the species in Andalusia. Nevertheless, the search for new populations must continue, above all in Sierra Nevada and Sierra de Baza-Filabres and in other sectors of the region such as Sierra Morena and the western third of the Betics Mountains.

The presence of the species in the north of the provinces of Granada and Almería supports the findings of both Fernández- Salvador (2002) and Gisbert and García-Perea (2003) in the neighbouring Murcia region. Nonetheless, Cabrera's vole is not included in the Regional Red Data Book (Robledano *et al*., 2006). Further field work is needed to clarify the status of the species in south-eastern Spain.

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