Rediscovering *Carduncellus matritensis*: assessing the conservation status of an Iberian endemic

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Abstract The plant *Carduncellus matritensis* (Cardueae, Compositae) was formerly known from only a single locality: Cerro Negro in Madrid Province, Spain. It is one of the six endemic species of the Spanish flora considered to be extinct. The causes of its presumed extinction were anthropogenic: the growth of the city of Madrid subsumed the locality into the city, such that Cerro Negro is now a railway station. During 2021–2022 we discovered three new populations c. 50 km south of the type locality, with 130–166 mature individuals. Habitat fragmentation and degradation are the most significant threats facing the three populations. We categorize the conservation status of the species as Critically Endangered according to the IUCN Red List criteria. To avoid the loss of this species, we recommend both in situ (creation of micro-reserves) and ex situ (seed storage) conservation measures.

Keywords Cardueae, *Carduncellus matritensis*, Critically Endangered, endemic, extinct species, Madrid, magnesium-rich clays, Spain

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The genus *Carduncellus* Adans. (Cardueae, Compositae) includes nearly 25 perennial species (following the taxonomic criterium of Vilatersana et al., 2000; López González, 2012), distributed almost exclusively in the Iberian Peninsula and North Africa and including many endemic taxa. *Carduncellus matritensis* (Plate 1a,b) was described by Carlos Pau based on herbarium specimens collected by Juan Isern (Pau, 1904). It is a species formerly known to have inhabited only a single locality: Cerro Negro in Madrid province, Spain (Fig. 1). It is one of the six endemic species of Spanish flora listed as extinct and it had not formerly been collected since 1935 (Bañares et al., 2004; Moreno, 2008). The cause of its extinction was the growth of the city of Madrid: during 1956–2005 the human population increased by > 225%, and the area covered by the infrastructure of Madrid increased by > 600% (de Pablo et al., 2017). Habitat fragmentation and habitat disturbance are two significant factors that increase extinction risk (Hanski, 1998). The taxonomic status of *C. matritensis* has been disputed because of the scarcity and poor preservation of herbarium material, which led to the subordination of *C. matritensis* either under *Carduncellus pinnatus* (Desf.) DC. (Cutanda, 1861; Rivas Goday & Rivas Martínez, 1967) or *Carduncellus monspelliensium* All. (López González, 2012; Mateo Sanz & Crespo, 2015).

We discovered three new populations of *C. matritensis* during May 2021–May 2022 in Toledo Province, c. 50 km south of the type locality (Fig. 1), highlighting the importance of botanical exploration even in suburban areas. Following its rediscovery, we examined specimens of *C. matritensis* in three herbaria (BC, MA and MAF) and revised the description of the species to confirm its identity. The new specimens matched *C. matritensis*, and with high-quality living material now available we reject the subordination of this species under either *C. monspelliensium* or *C. pinnatus*: *C. matritensis* is a separate, well-defined species (Supplementary Fig. 1). The capitula of *C. matritensis* are subtended by a verticil of very large bracts with green leaf-like limbs (Plate 1b), which are missing from the heads of *C. monspelliensium* and *C. pinnatus*. Bracts in the capitula of *C. matritensis* have very large, showy, cucullate appendages (Plate 1b); even though *C. monspelliensium* bracts have cucullate appendages, they are much smaller and are usually limited to the innermost row. The leaves are also different, especially from *C. pinnatus*, a North African and Sicilian species with leaf segments disposed at almost 90° from the rachis. Preliminary DNA sequencing supports this statement (R. Vilatersana et al., 2022, unpubl. data). During our herbaria searches we located two additional entries for *C. matritensis* in MAF, collected from the type locality in 1968 and 1972. Therefore, the extinction of *C. matritensis* in the Cerro Negro occurred later than previously presumed.

Carduncellus matritensis is a hemicryptophyte endemic to magnesium-rich expansive clays. These clays are rare worldwide but in the Iberian Peninsula they are frequent in the Tajo River trench (in south-south-east Madrid and the

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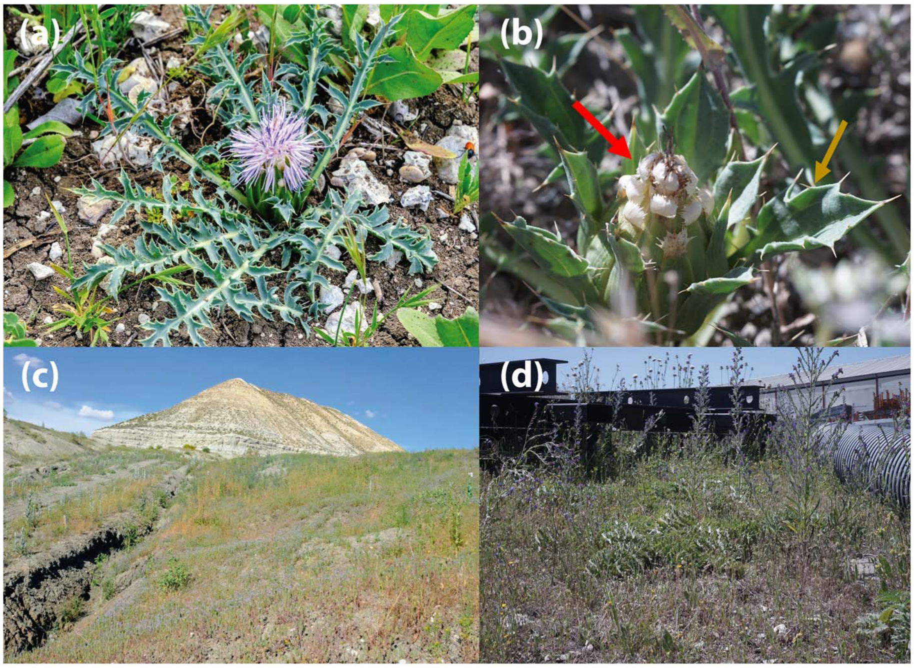

PLATE 1 *Carduncellus matritensis*: (a) plant, (b) detail of bracts: left arrow, cucullate appendages in intermediate bracts; right arrow, external bracts, (c) habitat in Cerro de Magán, (d) habitat in Villaluenga de la Sagra. Photos: E. Luengo (a,c) and A. Susanna (b,d).

Sagra region, Toledo; Fig. 1; Domínguez Díaz et al., 1997), which experiences a mean annual rainfall of 300–400 mm (Chazarra et al., 2011). Its few known populations are found in deep, fertile soils in topographically depressed terrain, at the base of hills or in dry meadows of therophytes with specialized hemicryptophytes such as *Cynara tournefortii* Boiss. & Reut. and *Klasea flavescens* (L.) Holub (Luengo et al., 2017). We classify these soils as vertisols based on their physical characteristics: high expansiveness when wet, with an increase in volume > 10%, and in the dry season the appearance of wide shrinkage cracks that cause strong vertical mixing of the edaphic profiles, rapid desiccation in profile depth and root breakage. Within the potential distribution area of the species (787 km^2; Fig. 1) almost all of the non-urban land with this soil type is cultivated, with such cultivation being incompatible with the presence of the species. Other associated taxa, such as *C. tournefortii*, are also threatened by this intensive agriculture.

We counted > 250 mature individuals (130 in 2021 and 166 in 2022) of *C. matritensis*, with c. 80% of individuals in a single population (Table 1) and only c. 10% of individuals flowering in 2022. However, conducting a census is not straightforward. Firstly, this species shows clonal growth, which makes differentiating between genets and ramets difficult. We estimated the numbers of individuals by considering each patch of tangled rosettes with one or several capitula as a single genet. Secondly, both the development and reproduction of individuals of this species are conditioned strongly by the presence of spring rainfall, which causes significant oscillations in population size. All known populations of this species are subject to significant anthropogenic pressures (roads, industrial estates, intensive agriculture; Plate 1c,d) that, in combination with stochastic environmental and demographic factors, increase the risk of the extinction of this species.

Our findings support a change in the conservation status of *C. matritensis* from Extinct (Bañares et al., 2004) to Critically Endangered based on IUCN criteria (IUCN, 2012) B1ab(i,ii,iii) and B2ab(i,ii,iii) because its extent of occurrence is < 100 km^2 (B1) and area of occupancy is < 10 km^2 (B2), with estimates of 5 km^2 and 4,000 m^2 respectively, it is severely fragmented (a/b) and there is continuing decline of extent of occurrence (i), area of occupancy (ii) and habitat quality (iii) (Plate 1c,d). We do not yet have numerical data on population evolution to assess the species based on other quantitative IUCN criteria (i.e. the A and E categories); however, because of the intense transformation of this area since at least the 1970s we presume there has been a significant reduction of the population size and/or the disappearance of (sub)populations. In addition, the main causes of this reduction (e.g. urban pressure and the aggressive nature of intensive agriculture) continue. The species now also faces a new potential threat in the form of the proliferation of photovoltaic solar plants throughout this region, with some having been installed recently and others projected to be installed in areas suitable for the species. Given the small number of populations and individuals of *C. matritensis* (Table 1), measures need to be taken to ensure the populations remain viable. In situ conservation will require the creation of micro-reserves (Laguna, 2005), which are an effective mechanism to protect small areas. One advantage of this approach in this case is that it is already employed by the Autonomous

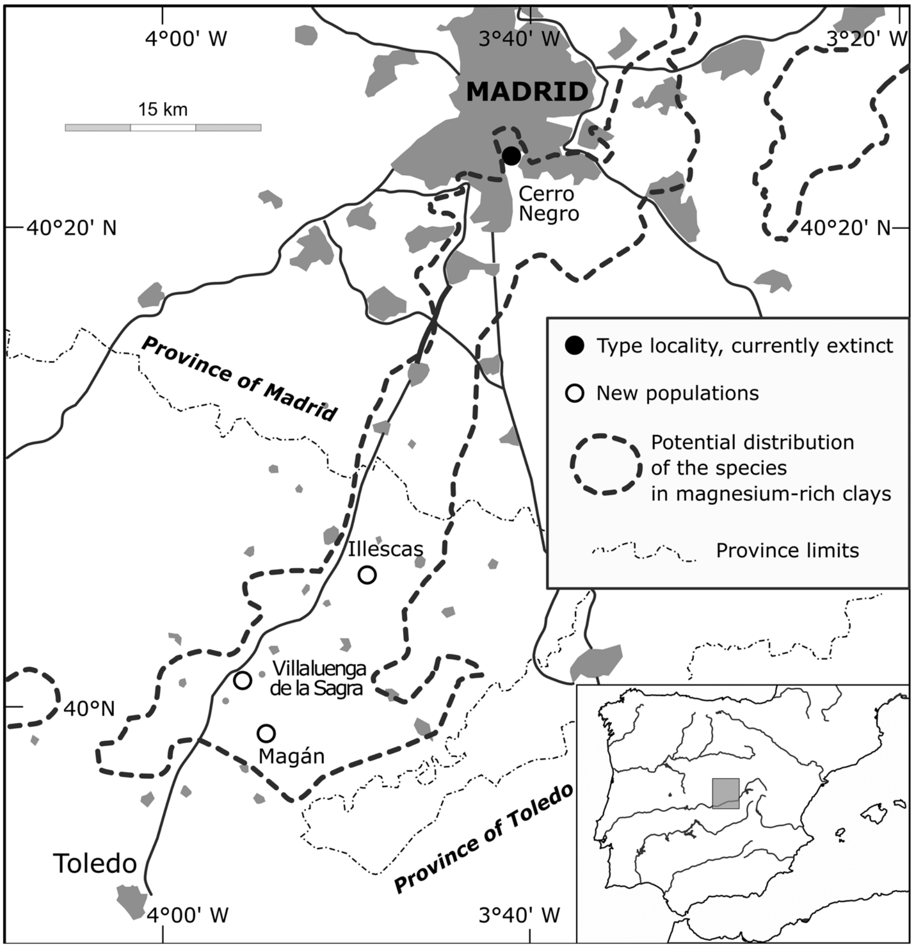

FIG. 1 Locations of the type locality of *Carduncellus matritensis* and of the three populations discovered in 2021–2022 in the Province of Toledo, Spain.

TABLE 1 Characteristics of the three newly discovered populations of *Carduncellus matritensis*.

Locality	Geographical coordinates	Number of mature individuals 2021	Number of mature individuals 2022	Area of occupancy (m^2)
Villaluenga de la Sagra	40°01′09″N 3°56′10″W	110	136	3,600
Cerro de Magán	39°59′14″N 3°54′31″W	20	9	75
Illescas[1]	40°05′28″N 3°49′44″W		21	320

[1]Only in the 2022 census.

Government of Castilla-La Mancha, which is legally in charge of the protection of *C. matritensis*. We have now stored seeds of this species at the Germoplasm Bank of the Royal Botanic Garden of Madrid, for future reintroductions or reinforcements. In addition, we recommend further field research to locate any potential additional populations, and research on population genetics and demography, to support the design of long-term conservation strategies for this species.

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Author contributions Study design: all authors; fieldwork: EL, JMM-L, RdP; writing: all authors.

Conflicts of interest None.

Ethical standards This research abided by the *Oryx* guidelines on ethical standards.

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