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First demographic assessment of the recently discovered population of the narrow endemic *Femeniasia balearica* (Asteraceae) from the Balearic Islands (Western Mediterranean)

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Abstract. Demographic data on threatened species is crucial to understand their conservation status and make management decisions when necessary, which is especially relevant for narrow endemic species with isolated populations. This is the case of *Femeniasia balearica* (J.J. Rodr.) Susanna, a narrow endemic cushion-like shrub that grows in coastal areas of northern Menorca (Balearic Islands, western Mediterranean Basin) and catalogued as Vulnerable according to the IUCN categories. Recently, a new population has been located in the center of the Serra de Tramuntana of Mallorca (Balearic Islands). In this study, the demographic status of the population from Mallorca has been studied, geolocating all of the individuals with a differential GPS to obtain a detailed map. Data on stage of development (seedling, vegetative or reproductive), morphometry and the overall status of all the individuals have been compiled. A total of 116 individuals and 96 seedlings have been counted. The fact that most of the individuals are reproductive (86.70%) and the confirmation of the presence of seedlings suggest that the population may be maintained in the future. This study provides valuable data on the demographic status of the new population of the species, but long-term monitoring is necessary for analyzing demographic trends.

Keywords. *Femeniasia balearica*, conservation biology, demographic status, threatened species, narrow endemics, Balearic Islands, Mediterranean basin.

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Introduction

The knowledge of demographic status of threatened plant species is crucial in conservation biology (Hutchings, 1991; Marsh & Trenham, 2008; Lavery *et al*., 2021). Indeed, population monitoring of threatened species represents one of the main tools in plant conservation biology, providing valuable information such as the total number of individuals in a population, the proportion of reproductive and vegetative individuals or the presence of seedlings (Palmer, 1987). However, there is a lack of basic knowledge in essential aspects for the conservation of many species, such as distribution, ecology, population demographics, threats or conservation status (Heywood, 2017). In this sense, species surveys are essential to provide knowledge of the basic biology of threatened plant species (Xu & Zang, 2023).

To apply *in situ* conservation strategies, such as the protection and restoration of natural habitats of threatened species, it is necessary to have information regarding the demographic status of a species to guarantee adequate conservation (Kesseli, 1992; Elzinga *et al*., 1999). The methodology to establish the threat category is defined worldwide based on the IUCN criteria (Le Breton *et al*., 2019). Hence, it is absolutely essential that this information be generated and reviewed periodically (Conde *et al*., 2019). Management techniques of threatened plant species have notably been developed in recent years as demonstrated by the works carried out in this field (e.g., Goñi *et al*., 2015; Marrero *et al*., 2015; Rita & Cursach, 2015). There are various

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demographic parameters that regulate the size of a population (i.e., survival, growth, fecundity), and changes on those parameters can have very different impacts on demographic status (Morris & Doak, 2002). Therefore, it is necessary to evaluate which stages of the life cycle are most critical for population growth to focus on them when designing management strategies (Schemske *et al*., 1994; Heywood & Iriondo, 2003). Numerous studies show that previous knowledge about the status of populations of threatened species allows to take decisions that improve their conservation status through management strategies that guarantee their continuity (e.g., García, 2003; Gaudeul & Till-Bottraud, 2004; Cursach *et al*., 2020a).

Censuses of plant species in restricted environments require high geographic accuracy of the information. In this aspect, satellite-based geopositioning systems (global navigation satellite systems, GNSS) are very useful to capture the presence of individuals (Cursach *et al*., 2020a; Cerrejón *et al*., 2021). Indeed, the use of real-time kinematic global positioning systems (RTK-GPS), which provide an error level of centimeters, allows individuals to be precisely located (Leica Geosystems, 2013). This technology allows precise mapping of the distribution of each individual in an endangered species population (Cursach *et al.*, 2020a).

The Mediterranean Basin represents one of the main biodiversity hotspots on the planet (Myers *et al*., 2000). Mediterranean islands, in particular, have a high endemic richness (Greuter, 2001), making them important centers of plant biodiversity (Greuter, 1995; Pasta *et al*., 2017; Guardiola & Sáez, 2023). Species on these islands are especially vulnerable to anthropogenic disturbances (Sax & Gaines, 2008; Fernández-Palacios *et al*., 2021), and many of them require urgent protection measures (Kier *et al*., 2009; Fenu *et al*., 2020). These species often have limited number of populations, small population sizes, and/or low population density (McKinney, 1997; Matthies *et al*., 2004; López-Pujol *et al*., 2013), making their conservation status fragile (Ouborg *et al*., 2006; Silcock *et al*., 2011). However, there is still a gap in knowledge about the demographic status of many endemic species to Mediterranean islands and the existing information needs to be updated (Sáez *et al*., 2017; Orsenigo *et al*., 2018).

In this study, we focused on *Femeniasia balearica* (J.J. Rodr.) Susanna (=*Carthamus balearicus* (J.J. Rodr.) Greuter) (Compositae) which is a threatened narrow endemic species (*sensu* Médail & Baumel, 2018) from the Balearic Islands (western Mediterranean Basin), with only three known populations on the north coast of Menorca (Vilatersana *et al*., 2007) and a population discovered in recent times in Mallorca (Sáez *et al*., 2017) (Figure 1) ('population' corresponds to the 'subpopulation' used in IUCN guidelines (IUCN, 2022)). Given the gap of knowledge of the demographic status of the new population, we carried out an integral survey to generate a distribution map with high accuracy (error < 0.05 m) and collected biological data from all the individuals to characterize this population. Also, information on the ecological context of the species in the new population was obtained. Specifically, (i) we defined the geographical limits of the new population and obtained a detailed cartography according to biometric characteristics, general conditions and stage of development, and (ii) we obtained information regarding the accompanying flora. Finally, we discussed the current and potential threats to the population from a conservation point of view.

Material and Methods

Study species

Femeniasia balearica (accepted name according to POWO (2024)) is a range-restricted species assessed as Vulnerable under the A1e; B1ab(iii)+2ab(iii); D2 criteria according to the red list of the Spanish vascular flora (Moreno, 2008) and under the C2a(i) and D2 criteria in accordance with the red list of the Balearic Islands vascular flora (Sáez *et al*., 2017). The species is legally protected both at the National level (Real Decreto 139/2011) and the European level (Habitats Directive of the European Council, 1992). It is also included in the Bern Convention 1991 and, at the request of the Balearic Islands Government, a management and conservation plan was elaborated to generate knowledge about the basic biology of the species in the populations of Menorca based on *in situ* and *ex situ* experiments and proposed actions to guarantee its survival in the future (Conesa *et al*., 2003). *Femeniasia balearica* is also among the 50 most endangered plant species of the Mediterranean Islands according to the IUCN (Pasta *et al*., 2017).

Furthermore, within the LIFE+ LIFE07/NAT/E/000756 (2009-2014) project, habitat restoration actions have been performed in the area with the largest population of the species (Cala Mica-Binimel·là (BIN), see Figure 1). This species is only distributed in three geographically isolated locations, defined by Vilatersana *et al*. (2007) as three different management units based on the genetic variability of the population, in the northern coast of Menorca (Sáez *et al*., 2017). Also, the German botanist H. M. Willkomm cited a population in the mountains of la Victòria (Alcúdia), in the north of Mallorca, in 1873, but this citation may be an error as there is not an herbarium specimen and it has never been found again (Willkomm, 1876). Additionally, one population was discovered in recent times in Mallorca (Sáez *et al*., 2017), at the center of the Serra de Tramuntana (Figure 1). Moreover, the first genetic study indicates that the populations of Menorca and Mallorca are genetically differentiated (Villanueva-Raisman *et al*., 2023).

Femeniasia balearica is a long-lived perennial cushion-like shrub (Conesa *et al*., 2003), which can reach up to 150 cm in height (Pasta *et al*., 2017). The leaves measure 13-25 mm and are dimorphic: the young ones are linear and tridentate in the upper half, while the old leaves are reduced to the nerves, which are divided superiorly into three hard and divaricated spines -very characteristic of the species- provided in the middle part with two other small spines (Rodríguez-Femenias, 1904; López-González, 2014). A reduced number (8-20) of yellow flowers are arranged in small capitula (14-16 mm in diameter), and the anthesis occurs from May to July (Figure 2). The species is self-incompatible, and pollination is mainly entomophilous, although anemophilous pollination also appears to be present (Gil, 1994). It has a large number of pollinating insects, belonging to Diptera, Coleoptera, Lepidoptera and Hemiptera (Conesa *et al*., 2003). Each capitulum produces about 10 fruits that are dispersed between late summer and early autumn. Seed dispersal is limited due to the large size of the seed relative to the pappus, although strong winds can promote occasional long-distance dispersal (Gil, 1994), and germination in the field usually occurs in autumn (Conesa *et al*., 2003; Cardona & Gil, 2013).

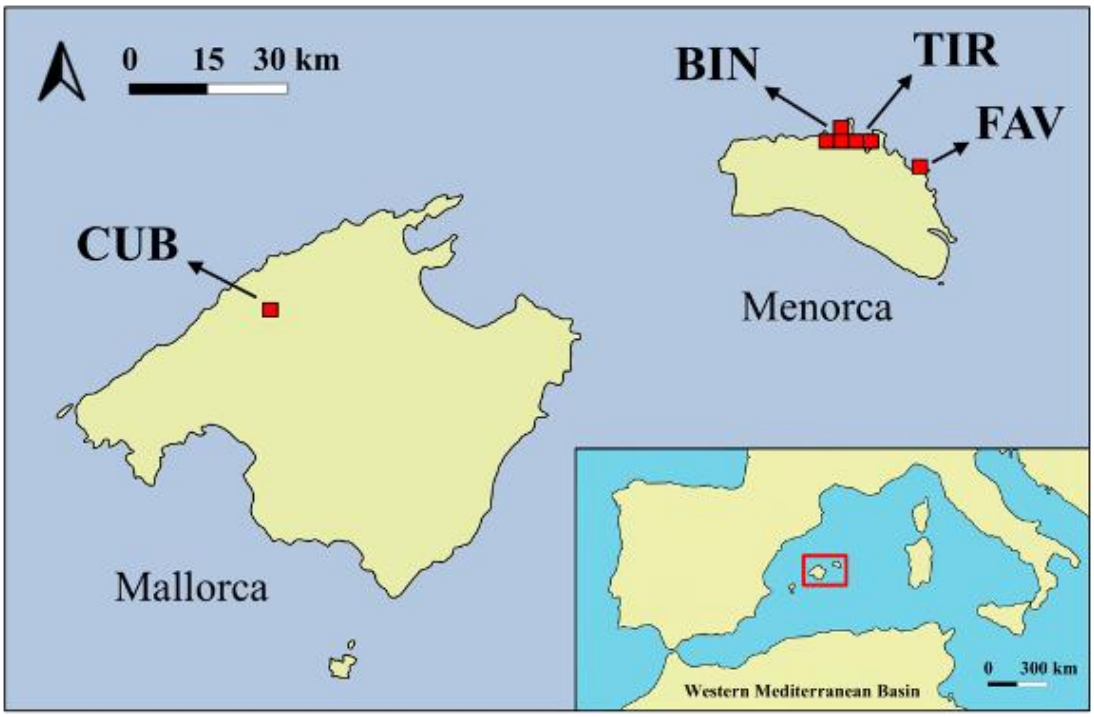

Figure 1. Map of the location of the subarchipelago of Mallorca and Menorca in the Western Mediterranean Basin, with the geographical distribution of *Femeniasia balearica* in UTM squares of 2.5 × 2.5 km (in red) (source: BioAtles Project, available at http://www.ideib.es). The four populations of the species are: CUB, Pla de Cúber; BIN, Cala Mica-Binimel·là; TIR, Fornells-Cala Tirant; FAV, Mongofra-Pou d'en Caldes-Favàritx. CUB is located in the serra de Tramuntana of Mallorca, whereas BIN, TIR and FAV are located at the north coast of Menorca.

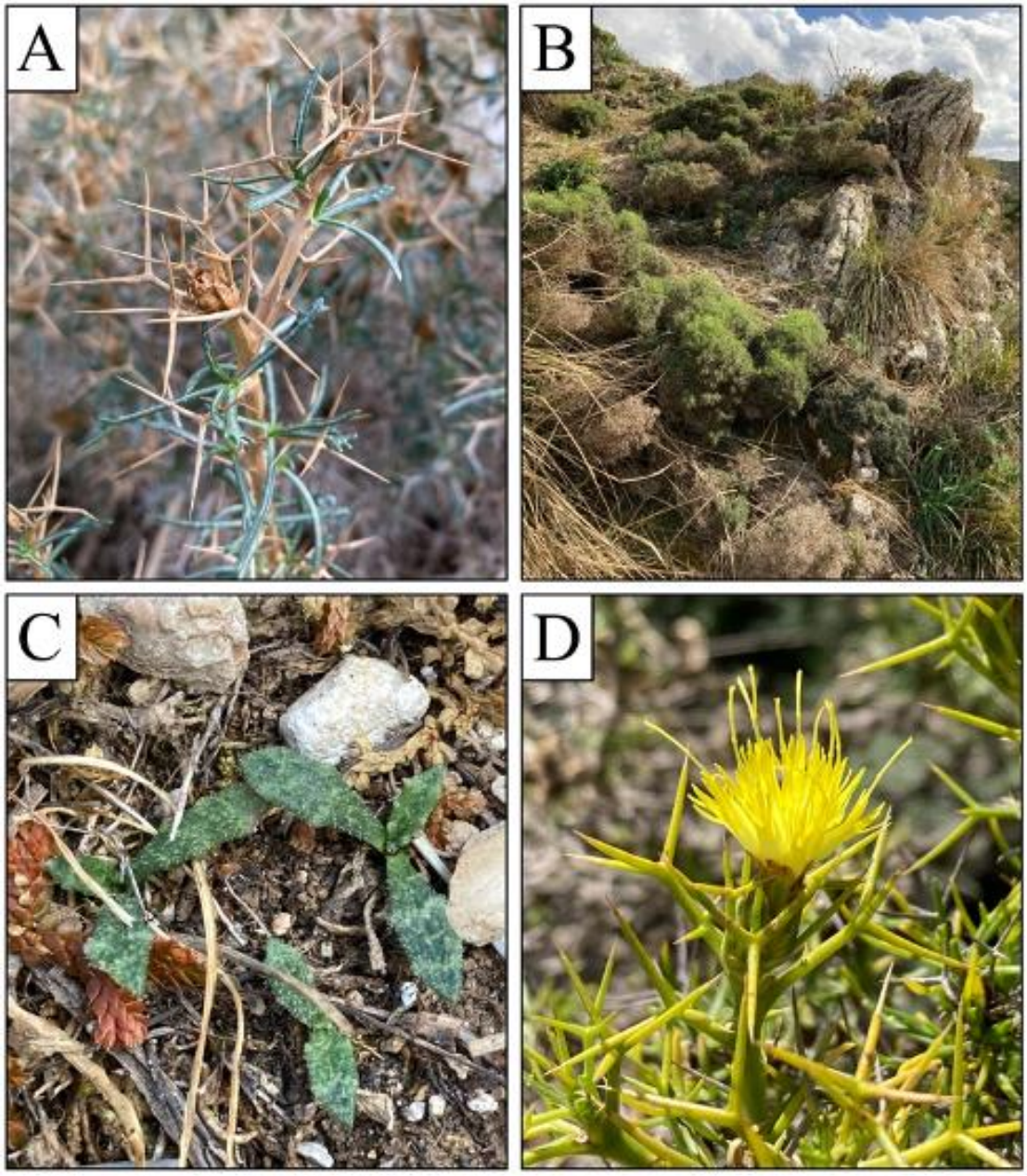

Figure 2. Traits of *Femeniasia balearica*. A, Branch in which the two morphologies of leaves can be seen: the green ones are young and the old are brown and transformed into thorns (image taken in September 2023); B, Habit of the species (May 2023); C, Group of three seedlings approximately 20 days old (largest leaves are approximately 1 cm long) (May 2023); D, Inflorescence morphology (capitulum is approximately 14-16 mm in diameter) (June 2023).

Study site

The Cúber population (CUB, hereafter) was located at the center of the Serra de Tramuntana, in the Cúber valley (39°47'N, 2°47'E) at 850 masl (Figure 1). The species grew mostly on an area of rocky wall with a steep slope or in its immediate vicinity. The zone presented formations of low vegetation (generally less than 1.50 m in height) dominated by *Ampelodesmos mauritanicus* (Poir.) T. Durand & Schinz. *Femeniasia balearica* shared the area with other cushion-like endemisms such as *Astragalus balearicus* Chater and *Teucrium balearicum* (Coss. ex Pau) Castrov. & Bayon.

Demographic survey

In December 2022, an exhaustive demographic census was carried out in CUB. Following the direct counting method described by Iriondo (2011), we carried out the census of the entire population. The prospecting area was extended 50 meters around the limits of the population in order to detect new individuals. All individuals were georeferenced using a differential GPS (Leica RX1200 RTK GPS) which provides a maximum deviation of 0.05 m that allowed individuals to be accurately located (Leica Geosystems, 2013). The information collected during the census was captured on maps using the QGIS application version 3.28. The extent of occurrence (EOO) and the area of occupancy (AOO) were calculated (subtracting unsuitable areas such as those occupied by the sea) following the IUCN (2022) criteria. Data from Fraga (2018) were used for establishing the limits of the populations from Menorca, and the EOO and AOO were calculated using Area Measuring tool of the QGIS version 3.28.

For each plant, we recorded the development stage, plant size and the general condition. Development stages were classified in (i) seedling for those with small height (< 8 cm), reduced number of leaves (<16 leaves) and/or cotyledons, (ii) vegetative for those that were not seedlings but did not show signs of flowering and (iii) reproductive for those individuals with signs of flowering in the previous season (i.e., remains of inflorescences or its insertion scars (see Figure 2A). Following the methodology used in censuses of other populations of the species (Mercadal, 2012; Insula, 2013) and adding the height parameter, we collected data on the following morphometric measurements: maximum length, width (perpendicular to the maximum length) and height (from the base of the trunk to the highest part of the plant). In some cases, nearby individuals grew by overlapping their branches and plants can develop new branches from buried or semi-buried trunks (Sáez *et al*., 2017), although vegetative reproduction has not been observed (Gil, 1994). Therefore, for those few cases in which it was impossible to differentiate at the individual level, we treated them as polyplants, as has been also done in other studies carried out in Menorca (Conesa *et al*., 2003; Mercadal, 2012; Insula, 2013).

We calculate the size index of the individuals adapting the index described by De Cáceres *et al*. (2013). We used an estimate of plant diameter, which consists of the width and length average of each plant. Thus, the index was calculated as the average between the diameter and height of each individual. Polyplants were not considered in this case since they are not representative of the size index.

$$\text{Size index} = \frac{\left(\frac{\text{Width} + \text{Length}}{2}\right) + \text{Height}}{2}$$

We tested the effect of plant size on the reproductive stage in R v. 4.4.0 (R Core Team, 2024). Thus, we implemented a generalized linear model using a binomial distribution including size index as predictive variable and reproductive stage (yes/no) as response variable (Zuur *et al*., 2009). Likelihood ratio tests to determine the significance of variables were performed using the '*Anova*' function from the '*car*' R-package (Fox & Weisberg, 2019). The figure was created using the '*ggplot*' function from the '*ggplot2*' R-package (Schloerke *et al*., 2024).

Regarding the general condition, we used the following categories according to the previous literature (Mercadal, 2012; Insula, 2013): good for those plants with all branches in good condition, i.e., without any signals of suffering damage; medium, for those plants that were in good condition, but had at least half of the branches dry; bad for those plants that had practically all of their outer branches dry (in many cases the plants appeared to be dead, but with the main trunk having tender shoots); dead for those plants that were completely dead and without any attempt to sprout.

Seedlings monitoring

During a year (from December 2022 to December 2023), the emergence of seedlings was monitored quarterly. Due to the reduced dispersal ability of the species (Gil, 1994), we established a radius of two meters around each reproductive individual for the search of seedlings. Seedlings without any adult leaves were not considered to ensure that all seedlings belonged to the study

species. From the compiled data, we obtained the proportion of seedlings that survived the summer period. For each seedling, we recorded the number of cotyledons and adult leaves, length, width and the distance to the closest reproductive plant -measured as the distance to the center of this plant- as well as the geolocation using differential GPS (Leica RX1200 RTK GPS).

Habitat characterization

To characterize the habitat of *F. balearica* in CUB, we collected information about the accompanying flora through three linear transects of 50 meters, noting the presence of plant species every 20 cm (i.e., 750 sampling points). In this way, the frequency of appearance of each species was calculated as the frequency of occurrences in relation to the total number of sampling points. For those species present in the study area but not recorded along the transects a frequency of 0.50 was assigned to take them into account for diversity analysis (see Cursach *et al*., 2020b). The transects were carried out in May 2023 which corresponds to the flowering peak of most species in the area. In addition, the value of species diversity has been calculated using the Shannon Index (Shannon, 1948). Plant taxa followed the nomenclature of Plant of the World Online (POWO, 2024), except for *Anagallis arvensis* L. in which case *Flora iberica* (Pujadas, 1997) was used. Moreover, we collected three rock samples for mineralogical characterization at the laboratory. Finally, data for the monthly average temperature (from 2009 to 2019, except for 2011 and 2015) and the monthly accumulated precipitation (from 2011 to 2016) of the CUB population were obtained from the meteorological station of Son Torrella (39°47'34"N, 2°47'16"E), provided by the Spanish State Meteorological Agency (AEMET).

Results

Demographic survey

The CUB population of *F. balearica* consisted of 116 plants (plus 4 dead individuals), 3 of which were polyplants. A detailed map of each individual of the population was generated (Figure 3; Figure S1), and its geographical limits were established. The population was located between 810 and 860 masl, within an area of 7346 m^2, and the total area occupied by *F. balearica* individuals in CUB is 68.43 m^2. Taking into account the citation of the species in La Victòria (Alcúdia) by Willkomm in 1873, we prospected that area during the flowering period of the species in June 2024 but without success. The EOO of the species (considering all populations) was 327.80 km^2 (without considering the area occupied by the sea) and the occupied area (AOO) was 32 km^2 (using a 2 × 2 km grid). 86.70% of the individuals were reproductive plants and 13.30% were vegetative plants (Figure S2). Regarding the general condition, more than half (53.30%) of the population was in good condition, 28.30% was in medium condition, 15.10% in bad condition and 3.30 % was dead (Figure S3). The average plant length was 81.01 ± 3.82 cm (n=116) (3–180 cm) (average ± ES, min–max), the average plant width was 62.96 ± 3.04 cm (n=116) (3–147 cm), and the average height was 44.48 ± 1.87 cm (n=116) (4–94 cm). Regarding the size index, 28.45% of the individuals showed a size index value higher than 75 cm, 41.38% of the individuals showed values between 45-75 cm, 22.41% of individuals showed values were between 15 and 45 cm, and only 7.76% of the individuals showed values lower than 15 cm (Figure 3A). Also, reproductive stage was significantly related to the size index (χ^2=78.90; df=1; p<0.001). Specifically, individuals with a size index greater than 30 were mostly reproductive and those with values lower than 30 were mostly vegetative (Figure S4).

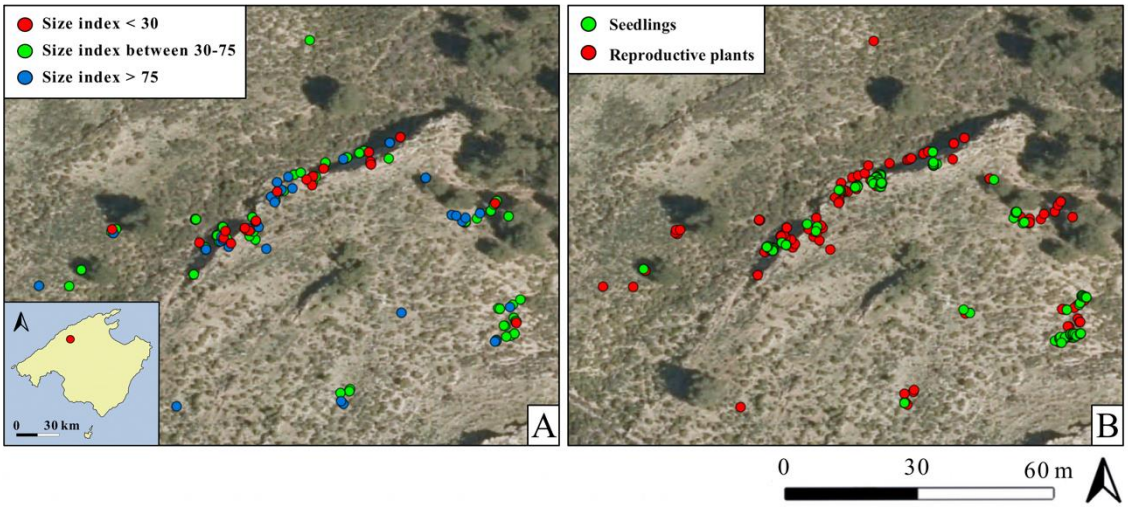

Figure 3. A: Distribution of *Femeniasia balearica* individuals in the CUB population according to size index. In order to facilitate visualization, data were grouped into three size index classes: < 30 (red), 30-75 (green) and > 75 (blue). B: Distribution of seedlings detected in December 2023 in CUB. Seedlings are represented as green dots and reproductive plants as red dots.

Seedling monitoring

Seedlings were observed in the field in both spring and autumn, with the majority emerging in autumn (Figure 4). The first seedlings were detected at the end of April 2023, and their number increased until mid-June. Only 4 out of the 21 seedlings survived the summer period. Seedling emergence began again in September, with an important increase in December, adding 92 seedlings to the summer survivors (Figure 4). The average distance of seedlings to the closest reproductive plant was 81.38 ± 4.41 cm (n=96) (13–280 cm) (Figure 3B). The average number of adult leaves of the seedlings was 2.57 ± 0.22 cm (n=93) (1–14 cm); the average number of cotyledons was 0.95 ± 0.09 cm (n=93); the average length of the seedlings was 2.35 ± 0.13 cm (n=93) (0.50–7 cm) and for width was 1.22 ± 0.10 cm (n=93) (0.20–4.50 cm). We found 34 seedlings with two cotyledons, 20 with one cotyledon and 39 without any. Most of the seedlings were detected in areas with stable soil, sometimes between the layer of bryophytes that covers the soil in the least eroded areas.

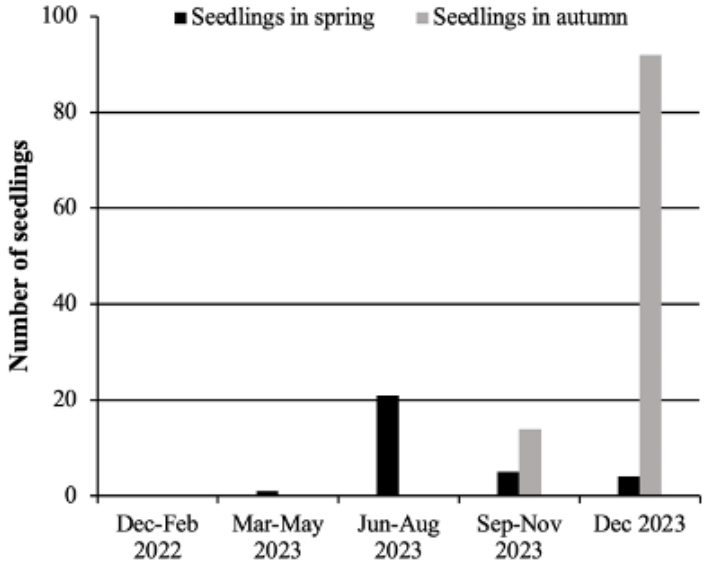

Figure 4. Number of seedlings observed in CUB quarterly from December 2022 to December 2023. Black bars indicate seedlings germinated in spring and grey bars indicate autumn seedlings germinated in autumn.

Habitat characterization

The accompanying flora of *Femeniasia balearica* in CUB was composed of a total of 90 taxa (see Tables S1 and S2 for details), and the most frequent species were *Ampelodesmos mauritanicus* (appearing in 56.53% of the sampled points), *Brachypodium distachyon* (L.) P.Beauv. (44.93%), *Hypochaeris achyrophorus* L. (22%), *Asphodelus ramosus* L. subsp. *ramosus* (21.20%), *Astragalus balearicus* (9.47%), *Smilax aspera* L. (9.47%), *Dactylis glomerata* subsp. *hispanica* (Roth) Nyman (8.13%) and *Linum strictum* L. (7.60%). *Femeniasia balearica* appeared at 1.73% of the sampled points. The value obtained for the Shannon index was 3.03. Besides, the vegetation cover was high, since only 4.27% of the sampled points corresponded to bare soil or bedrock. Climatic data showed an accumulated precipitation of 1303.62 ± 97.96 mm/year (n=6) (1046.40–1691.40 mm/year), and an average temperature of 12.14 ± 0.15 ºC (n=9) (11.17–12.53 ºC) (AEMET). The mineralogical characterization of rock samples from the study area revealed that they belonged to the Dogger, i.e., a calcium carbonate material with clays rich in quartz that appears in different locations in the Serra de Tramuntana (pers. comm. Dr. J.J. Fornós). Finally, an elevated presence of non-native ungulates was observed in the study zone.

Discussion

Demographic status of the recently discovered population

In this study, we integrally georeferenced the CUB population of *Femeniasia balearica*, an endangered narrow endemic species from Menorca and Mallorca with only four natural known populations, using geolocation systems with high-accuracy (RTK-GPS) to obtain a precise map (error < 0.05 m). We also surveyed all individuals and monitored seedlings with the aim of generating the first demographic data of the recently discovered population.

The CUB population consists of 116 individuals located in a small area of about 7500 m^2, of which 68.34 m^2 are occupied by individuals of *F. balearica*. The high ratio of reproductive individuals (86.70%) and the presence of 96 seedlings seems to indicate that the population is well established in the area (Harper & White, 1974). However, the small size of the population highlights its weak demography and the necessity for a long-term study to assess the demographic trends. Regarding the spatial patterns, most of the individuals are concentrated in a rocky outcropping area. Thus, this area would be particularly interesting for the establishment of permanent plots for future demographic studies. Furthermore, the GPS data and information about each individual generated from this study will be very useful for demographic works in the future.

Comparing our results with demographic data from Menorca populations (Conesa *et al*., 2003; Mercadal, 2012; Insula, 2013), CUB presents a higher proportion of individuals with a low index size although all the populations of the species are dominated by individuals with a medium size index, that provides demographic stability. In this sense, our data indicate that reproductive plants show higher size index than vegetative plants, which is a common strategy among plant species (e.g., Horvitz *et al*., 2002). Polyplants in Menorca represent close to a third percentage of the total of individuals (Conesa *et al*., 2003), while in CUB represent only 2.59%. This can be explained by the environmental and climatic differences between the two areas (see below). In fact, it has been observed that, in general, the plants in CUB are not as bushy and grow taller than those in Menorca.

In the CUB population, 19.05% of the seedlings detected in spring survived their first summer (Figure 4). This result aligns with that for many other Mediterranean species as the first summer period is the most critical period for their seedling development (Lloret *et al*., 1999; Cursach & Rita, 2012). In the populations of Menorca, no seedlings were observed by Mercadal (2012) and Insula (2013), although Fraga (2018) indicated an acceptable level of recruitment. Indeed, field experiments define an *in situ* seedling emergence of less than 2% -contrasting with the near 75% of *ex situ* germination- with an elevated mortality rate of seedlings during the first summer period (Conesa *et al*., 2001). In fact, in some populations of Menorca the hypothesis of mass recruitment phenomenon by waves has been considered (Conesa *et al*., 2003), since in many long-lived woody species seedling recruitment is an infrequent event that only occurs once in many years (Harper & White, 2017). This phenomenon could explain the relatively high number of seedlings found in CUB in December 2023 while in December 2022 no seedlings were found.

Considering these results, we recommend carrying out a study of the importance of the soil seed bank. Furthermore, the low distance (81.38 ± 4.41 cm) of the seedlings from the closest reproductive plant observed in CUB (Figure 4) confirms the low seed dispersal capacity already observed in Menorca by Gil (1994).

Differential habitat particularities among populations

The habitat of the species differs drastically between Menorca and Mallorca islands. Both mountainous areas of Mallorca and coastal areas of the Balearic Islands are interesting in terms of the endemic flora they encompass (Guardiola & Sáez, 2023). On the one hand, the CUB population corresponds to *Smilaco balearicae-Ampelodesmetum mauritanicae* Rivas-Martínez 1992, which is the typical plant community of mountain slopes in the Serra de Tramuntana (Llorens *et al*., 2021). With 90 taxa observed in the study site, the value of 3.03 obtained for the Shannon index evidences a high diversity of species, according to Magurran (2004). On the other hand, the populations in Menorca corresponds to *Launaeetum cervicornis* O. Bolòs & Molinier 1958 (Pasta *et al*., 2017), a cushion-like plant community typical of rocky coast areas exposed to wind and saline spray (Llorens *et al*., 2021). Regarding the soil type, the CUB population presents calcareous soils, such as those from TIR and FAV. Indeed, *ex situ* germination tests indicated better results in calcareous soils than in acidic soils (Vicens, 2011).

The climatology of the two contrasted habitats where *F. balearica* occurs presents important differences. The CUB population is characterized by an accumulate precipitation of 1303.62 ± 97.96 mm/year (n=6) (1046.40–1691.40 mm/year), and an average temperature of 12.14 ± 0.15 ºC (n=9) (11.17–12.53 ºC) (AEMET). In contrast, climatic data from Menorca shows an accumulated precipitation of 550.30 ± 65.71mm/year (n=4) (357.40–641.70 mm/year), and an average temperature of 17.45 ± 0.26 ºC (n=4) (17.10–18.20 ºC) (AEMET data from the meteorological station of La Mola (39°52′31″N, 4°18′59″E) between 2006 to 2009 obtained from Cursach (2012)). In fact, the flowering phenology of *F. balearica* in CUB starts a month later compared to Menorca (observations of 2023). In the first half of May some flowering individuals were observed in Menorca (pers. comm. Dr. M. Capó), while in Cúber the flowering time started in the second half of June with a few flowering plants. It is known that altitudinal and, consequently, climatic differences vary the flowering time of species that have populations at different altitudinal gradients, so that populations at higher elevation above sea level delay flowering, as has reported for *Thymelaea velutina* (Pourr. ex Cambess.) Endl. (Bandera & Traveset, 2013) or *Euphorbia pithyusa* L. (Tomàs *et al*., 2017).

During the fieldwork work in the CUB population, we observed a high presence of introduced herbivores (horses, donkeys, sheeps and feral goats). Currently, this circumstance does not seem to pose an important risk of predation for the adult individuals of *F. balearica* because plants have thorns that provide them with some protection against herbivory due to an exaptation phenomenon (Capó *et al*., 2023). Although herbivory could be a threat to seedlings that have not yet developed spines (Mayol *et al*., 2017), the main problem posed by herbivores in the area could be habitat alteration by soil erosion and nitrification of the environment. Besides, after the winter time -when the population is covered by snow for several days- the water runoff also causes soil erosion, which can pose a problem for ecosystems (Calsamiglia *et al*., 2020). However, the predation of accompanying species such as *A. mauritanicus* can provide *F. balearica* more space to colonize since it seems to have low competitive capacity (Conesa *et al*., 2003), as has been reported in other endemic species such as *Rhamnus ludovici-salvatoris* Chodat (Gulías *et al*., 2002). In the case of *Naufraga balearica* Constance & Cannon, another narrow endemic species from Mallorca, it has been confirmed that a total lack of herbivores can be harmful since it is beneficial to competing species, but also the erosion caused by goats can make individuals disappear (Cursach *et al.*, 2013). Nevertheless, *F. balearica* seedlings in Menorca tend to grow better in small, slightly eroded open spaces as they are adapted to physical soil alterations (Deil, 2007; Montmollin & Strahm, 2005) whereas most of the seedlings in CUB have been found in stable places.

A fact that may have increased plant competition in the area is the ancient practice of control of *A. mauritanicus* meadows by annual burning in the Serra de Tramuntana to generate grass for the herds (Marcos, 1933). This practice was carried out until the first half of the 20th century and

the testimonies collected at that time indicate that it was a practice carried out for generations. It is known that *A. mauritanicus* withstands fire and has a rapid regeneration capacity, so its density becomes very high in burned areas, causing competition to other species (Vilà *et al*., 2001). It is possible that this circumstance has influenced the current distribution of *F. balearica* in Mallorca. Nevertheless, it seems that *F. balearica* is capable of resprouting after a pruning (Gil, 1994), therefore it could be able to resprout after a fire. On the other hand, in the current scenario of climate change, another risk facing the species is being left outside its optimal climatic range, in which situation the disappearance of the longest-lived individuals could produce a population decline (Harrison & Noss, 2017). Also, predicted changes in precipitation regimes towards more extreme events (Homar *et al*., 2010; Trenberth, 2011) could reduce seedling survival and increase soil erosion.

Implications for the species conservation

Given the autochthonous nature of the new population of *F. balearica* in Mallorca (Villanueva-Raisman *et al*., 2023) it becomes necessary to reassess the conservation status of the species. In Menorca, the number of individuals is distributed among the populations of BIN (2249 individuals), FAV (643 individuals) and TIR (526 individuals), with a total number of 3418 individuals in 2014 (Sáez *et al*., 2017), and the CUB population, with its 116 individuals, represents 3.28% of the total individuals of the species. Thus, the total number of populations of the species increases up to four. The latest threat category assessment of *F. balearica* -in which the new population was not considered- shows an EOO of 33 km^2 and an AOO of 28 km^2 using a 2 × 2 km grid (Fraga, 2018). Including the CUB population in these calculations, the EOO of the species increases up to 327.80 km^2 (without considering the area occupied by the sea) and the obtained AOO is 32 km^2 using a 2 × 2 km grid. All in all, according to the updated information, the species should be considered Vulnerable under criterion D2 (IUCN, 2022).

Conclusions

The CUB population of *Femeniasia balearica* seems to be well established in the area, although its extremely low number of individuals involves a high risk of collapse. Given the conservation status of the species, we strongly recommend future studies focused on unraveling the ecological role of *F. balearica* in CUB and obtaining demographic parameters that allow inferring the demographic trend of the species, not only of the new population but also of the other populations since available data needs to be updated.

Authorship information

MR: Methodology, formal analysis and investigation, writing - original draft preparation; JC: Conceptualization, methodology, formal analysis and investigation, writing - review and editing, Supervision.

Conflict of interest

None

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Supplementary materials

Figure S1. Distribution map of *Femeniasia balearica* in the population of CUB. Each red dot represents an individual.

Figure S2. Distribution map of *Femeniasia balearica* according to reproductive (green) and vegetative (red) individuals.

Figure S3. Distribution map of *Femeniasia balearica* according to the general condition of the individuals; green: Good; orange: Medium; red: Bad; white: Dead.

Figure S4. Effect of plant size (i.e., size index) on the reproductive stage of individuals. Reproductive stage values of 1 indicates reproductive individuals and values of 0 indicates non-reproductive ones.

Table S1. Accompanying species of *Femeniasia balearica* in the CUB population and their frequency of appearance in the transects respect to the sampled points (750 points).

Table S2. Accompanying species of *Femeniasia balearica* in the CUB population that have not appeared in the transects but were present in the study area.