Assessing the global conservation status of the rock rose *Helianthemum caput-felis*

Elena Sulis, Gianluigi Bacchetta, Donatella Cogoni
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Abstract The assessment of the conservation status of a species is the first step in developing a conservation strategy. IUCN Red Lists assessments are an important starting point for conservation actions and the most commonly applied method for assessing the extinction risk of a species. In this study, the global conservation status of the rock rose *Helianthemum caput-felis* Boiss. (Cistaceae), a perennial Mediterranean plant, was evaluated using the Red List criteria. The distribution of the species was determined by monitoring historical localities and all other suitable sites along the western Mediterranean coasts for 6 years. For each confirmed locality, the ecological and population parameters and the main threats were recorded; these data were used in a quantitative analysis of the species' extinction risk. Our findings indicate there have been several recent extinctions, and there is a continuing decline in the species' area of occurrence, habitat quality and number of reproductive plants. The main threats are related to human activities. Extinction models indicate a probability of quasi-extinction risk of c. 30% in five generations or c. 45% in three generations, with the species likely to become extinct in seven currently known localities within the next 10 years. Application of the Red List criteria indicates *H. caput-felis* should be categorized as Endangered. This study confirms that legal protection and passive conservation measures are insufficient to guarantee the persistence of a plant species. Active conservation and management actions are needed to protect this and other threatened species of the Mediterranean Basin.

Keywords Cistaceae, conservation status, extinction risk, *Helianthemum caput-felis*, IUCN Red List, Mediterranean flora, rock rose, threatened plant

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Introduction

Species face numerous threats, principally related to human activities, and biodiversity continues to be lost (Pimm et al., 1995; Butchart et al., 2010; Ceballos et al., 2015). Halting, or at least significantly reducing, the loss of biodiversity requires adequate investment and a comprehensive and reliable measure of conservation status (e.g. Balmford et al., 2005; Fenu et al., 2017; Orsenigo et al., 2018). Target II of Objective I of the Global Strategy for Plant Conservation 2011–2020 of the Convention on Biological Diversity (CBD; GSPC, 2008) is the preliminary assessment of the conservation status of the Earth's flora. Evaluation of species conservation status is required not only to evaluate progress towards the CBD's Aichi Targets of the Strategic Plan for Biodiversity 2011–2020 (Pimm et al., 2014) but also to identify and develop effective conservation strategies (Rodrigues et al., 2006; Mace et al., 2008; Fenu et al., 2015a; Rossi et al., 2016; Collen et al., 2016; Orsenigo et al., 2018). The IUCN Red List criteria (IUCN, 2001, 2012a) are the accepted standard for assessing the extinction risk of species (Rodrigues et al., 2006; Mace et al., 2008; Collen et al., 2016; Orsenigo et al., 2018).

Habitat Directive 92/43/EEC is the core strategy for nature conservation in Europe (Balmford et al., 2005; Pullin et al., 2009; Beresford et al., 2016; Fenu et al., 2017). Through the implementation of cogent conservation policies, the Directive promotes the maintenance of a favourable conservation status for a group of key species and habitats (European Commission, 1992; Rossi et al., 2016; Fenu et al., 2017). It is mandatory for EU member states that have full responsibility for their conservation efforts to monitor and report the conservation status of all species listed in the Directive (European Commission, 1992; Rossi et al., 2016; Fenu et al., 2017).

One of the key species listed in the Habitat Directive is the rock rose *Helianthemum caput-felis* Boiss. (Cistaceae), which is protected by several international, national and regional regulations. *Helianthemum caput-felis* is a thermophilous long-lived half shrub that grows in coastal environments under the direct influence of the sea, mostly on calcareous rocky cliffs with garrigues or scrublands; some populations grow on sand dunes in Majorca, fossil dunes in Morocco and rocky slopes bordering inland ravines (Fenu et al., 2015b). The species occurs in several disjunct and fragmented populations throughout the coasts

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of the western Mediterranean Basin (south-east Iberian Peninsula, Balearic Islands, Sardinia and north-west Africa; Fenu et al., 2015b and references therein). The global conservation status of *H. caput-felis* was previously unknown because only regional or local assessments were available, and there was little information on the species distribution and conservation status in Africa. *Helianthemum caput-felis* is categorized as Endangered in Europe (Bilz et al., 2011) and Spain (Agulló et al., 2010), and as Critically Endangered in Italy (Fenu et al., 2015b) and Algeria (Agulló et al., 2017). In addition, according to the European Habitat Directive *H. caput-felis* has an inadequate conservation status in Italy (Fenu et al., 2017).

Here, to help establish a conservation plan for *H. caput-felis*, we evaluated the species' global conservation status using the Red List criteria. We aimed to: (1) describe the species' range based on extensive field surveys, (2) quantify the size and structure of populations, (3) identify the main threats to the species' persistence, (4) assess the species' global conservation status, and (5) recommend appropriate conservation measures.

Methods

Data collection

The geographical distribution of *H. caput-felis* was determined through field surveys during 2012–2017 in all localities for which there were herbarium specimens or database records (Supplementary Table 1) and/or published data (Agulló et al., 2010; Fenu et al., 2015b; Sulis, 2016). Additionally, all sites along the coasts of Sardinia, the Balearic Islands and the Mediterranean coasts of Spain and Morocco with suitable ecological conditions for the species were surveyed. No surveys were made on the Algerian coast, for which information was obtained from Agulló et al. (2017).

In each locality where occurrence of the species was confirmed or discovered, the following analyses were undertaken. The geographical limits of confirmed localities were mapped and their area estimated using *ArcGis 9.2* (Esri, Redlands, USA). Localities separated by > 1 km were considered to be geographically separate. At each locality the altitudinal range, slope, aspect and habitat type according to the Habitat Directive were determined. Major threats to *H. caput-felis* were identified through field observations (except for Algerian localities), and categorized following the IUCN Threats Classification Scheme (IUCN, 2012b).

Where possible, population size was determined by a direct count of the total number of mature plants. In extensive localities, population size was estimated from a count of all individuals in 3–15 plots (each plot was 2 m^2; the number of plots depended on the location); in these cases population size (sensu IUCN, 2017) was estimated as $d \times A \times p$, where d is an estimate of density within the sampled plots, A is an estimate of the area occupied by the population, and p is an estimate of the proportion of mature individuals within the sampled plots. Populations were categorized in three size classes, defined a priori as small (< 100 individuals), medium (101–2,000) and large (> 2,000). The presence or absence of seedlings was also recorded in each locality by surveying the population several times during the recruitment season. Demographic data were collected on 98 permanent plots in six populations across the species range that were representative of the range of ecological conditions in which the plant grows (Table 1; Sulis et al., 2018). In each population, after excluding areas with marginal conditions for the species, permanent plots (2 × 1 m) were placed randomly in the area where the species was found; within the plots all plants present (a total of 821 in the 98 plots in the first census) were marked, mapped and monitored over a 3-year period.

Data analysis

To assess the extinction risk of *H. caput-felis* we used the Red List criteria (IUCN, 2001) and the guidelines for their application (IUCN, 2017), considering the criteria A, B and E. To determine whether *H. caput-felis* fulfilled criterion A we assessed any potential population reduction (observed, estimated or inferred) in the last 10 years or three generations, based on the area of occupancy (AOO; the area within the extent of occurrence occupied by the taxon, see below; IUCN, 2001).

To apply criterion B, the extent of occurrence (EOO; the area contained within the shortest continuous imaginary boundary that could be drawn to encompass all known sites of occurrence of a taxon, excluding cases of vagrancy) and the AOO were calculated from the distribution records. Extinctions that predated 1950 were excluded from these calculations. To estimate EOO, the minimum convex polygon that included all the occurrences was drawn (IUCN, 2017), with unsuitable areas excluded by deriving the corresponding α-hull using the Delauney triangulation (Burgman & Fox, 2003; Gargano et al., 2007; IUCN, 2017). The AOO was calculated by generating a 2 × 2 km grid with *ArcGis*.

To apply criterion E the estimated quasi-extinction risks of populations were calculated based on a demographic study that used both an integral projection model and a matrix population model (Sulis, 2016; Sulis et al., 2018; Supplementary Material 1). The matrix projection model was used to calculate the estimated quasi-extinction risk using the *popbio* package (Stubben & Milligan, 2007) in *R 3.1.2* (R Core Team, 2014). The mean generation time (T) extracted from the integral projection model was 15.97 years (3 generations = 47.91 years) and the mean value

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TABLE 1 Localities of *Helianthemum caput-felis* surveyed in this study, with altitudinal range, area, mean density ± SD, population size, whether seedlings were present, protection status, current status, source and the main threats (IUCN, 2012b). Localities in bold are those selected for study of detailed population dynamics (Sulis et al., 2018).

No.	Country, region	Locality (municipality)	Altitudinal range (m)	Area (ha)	Mean density ± SD (plants/m^2)	Population size[1]	Seedlings present	Protection[2]	Current status	Source	Threats
Italy											
1	Sardinia	Is Arutas (Cabras)	5–15	0.001		Small[C]	No	None	Confirmed	This study	4.1, 6.1, 8.1, 9.4
2	Sardinia	**Su Tingiosu–Porto Suedda (Cabras)**	5–25	12.743	4.8 ± 2.42	Large[E]	Yes	None	Confirmed	This study	2.1; 2.2; 3.2; 6.1; 8.1; 10.3
3	Sardinia	Seu (Cabras)						None	Extinct	This study	
4	Sardinia	**Capo Mannu (San Vero Milis)**	5–55	17.868	4.6 ± 2.25	Large[E]	Yes	SCI	Confirmed	This study	2.1; 2.2; 6.1; 8.1; 10.3
Spain											
5	Majorca	Punta es Bauç (Santanyí)	8–10	0.012		Small[C]	No	SCI	Confirmed	This study	6.1
6	Majorca	Colònia de Sant Jordi–Playa del Puerto (Ses Salines)	3–8	5.533	1.6 ± 0.74	Large[E]	No	SCI*	Confirmed	This study	1.1; 1.3; 6.1; 9.4
7	Majorca	**Colònia de Sant Jordi–Es Trenc (Ses Salines)**	2–4	0.493	3.0 ± 1.41	Large[E]	Yes	SCI	Confirmed	This study	6.1
8	Majorca	**Sa Ràpita–backdune (Campos)**	2–10	10.495	7.8 ± 5.57	Large[E]	Yes	SCI	Confirmed	This study	6.1
9	Majorca	Sa Ràpita–nautical club (Campos)	3–6	0.416	9.6 ± 1.85	Large[E]	Yes	None	Confirmed	This study	1.1; 2.1; 4.1; 6.1; 8.1
10	Majorca	Cap Blanc (Llucmajor)	90–110	101.359	2.5 ± 1.14	Large[E]	Yes	SCI	Confirmed	This study	4.1; 10.3
11	Majorca	Cala Pi (Llucmajor)	15–20	0.120		Small[C]	No	SCI	Confirmed	This study	1.1; 1.3; 4.1; 6.1
12	Majorca	Maioris (Llucmajor)							Not retrieved	This study	
13	Ibiza	Cala Conta (San José)							Not retrieved	This study	
14	Alicante	Cap d'Or (Teulada)	40–50	0.210		Small[C]	No	SCI*	Confirmed	This study	
15	Alicante	**Cala del Portitxolet (Teulada)**	9–14	1.038	1.4 ± 0.86	Large[E]	No	PMR*	Confirmed	This study	1.1; 1.3; 4.1; 6.1; 8.1
16	Alicante	L'Andragó–Les Platgetes (Teulada)	6–12	0.166	1.4 ± 0.54	Medium[C]	No	None	Confirmed	This study	1.1; 1.3; 4.1; 6.1
17	Alicante	Cala els Pinets, Cala Lobella, Cala de l'Advocat (Benissa)	10–20	2.203	2.9 ± 0.74	Large[E]	Yes	SCI*	Confirmed	This study	6.1
18	Alicante	Cala Fustera (Benissa)	7–11	0.182	1.2 ± 0.57	Medium[E]	No	SCI, PMR	Confirmed	This study	1.1; 6.1; 10.3
19	Alicante	Cala de les Bassetes (Benissa)	6–20	0.969	2.8 ± 1.04	Large[E]	Yes	SCI, PMR	Confirmed	This study	1.1; 6.1
20	Alicante	La Caleta (Calpe)	6–10	0.129	1.5 ± 0.79	Medium[C]	Yes	SCI*, PMR	Confirmed	This study	1.1
21	Alicante	Calpe (Calpe)	5–10	0.084	3.0 ± 1.37	Medium[C]	Yes	SCI*	Confirmed	This study	1.3; 6.1; 8.1
22	Alicante	Cabo de Santa Pola (Santa Pola)							Extinct	Serra et al. (2000); this study	

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Table 1 (*Cont.*)

No.	Country, region	Locality (municipality)	Altitudinal range (m)	Area (ha)	Mean density ± SD (plants/m^2)	Population size[1]	Seedlings present	Protection[2]	Current status	Source	Threats
23	Alicante	Cabo Cervera (Torrevieja)	5–14	1.676	1.1 ± 0.65	Large[E]	No	None	Confirmed	This study	1.1; 1.3; 4.1; 6.1; 8.1; 10.3
24	Alicante	Torrevieja (Torrevieja)	2–3	0.039	1.4 ± 0.82	Medium[C]	No	None	Confirmed	This study	1.1; 1.3; 6.1; 8.1; 9.4
25	Alicante	Cala Mosca and Punta Prima (Orihuela)	2–18	9.723	1.8 ± 0.34	Large[E]	Yes	None	Confirmed	This study	6.1; 8.1
26	Alicante	Rambla de las Estacas–Cala de las Estacas (Orihuela)	1–10	0.282		Small[C]	No	SCI*	Confirmed	This study	1.1; 8.1
27	Alicante	Barranco de la Cala del Capitan (Orihuela)	15–20	0.067		Small[C]	No	None	Confirmed	This study	1.1; 1.3; 2.2; 8.1; 9.4
28	Alicante	Casa de Los Leoncios (Orihuela)	15–20	0.381		Small[C]	No	SCI*	Confirmed	This study	1.1; 2.2; 6.1
29	Alicante	Cala Mosca–Playa Flamenca (Orihuela)	1–9	9.723	2.0 ± 0.50	Large[E]	Yes	PMR*	Confirmed	This study	1.1; 1.3; 4.1; 6.1; 8.1; 10.3
30	Alicante	**Cabo Roig (Orihuela**)	3–7	0.906	3.5 ± 1.67	Large[E]	No	None	Confirmed	This study	1.1; 1.3; 6.1; 10.3
31	Alicante	Punta de la Glea (Orihuela)	5–17	4.179	3.1 ± 3.53	Large[E]	Yes	PMR	Confirmed	This study	1.1; 1.3; 4.1; 6.1
32	Alicante	Dehesa de Campoamor (Orihuela)	5–10	0.117	1.5 ± 0.20	Medium[C]	No	None	Confirmed	This study	1.1; 1.3; 6.1; 8.1; 10.3
33	Alicante	Mil Palmeras (Pilar de la Horadada)	3–7	1.178	7.7 ± 1.53	Large[E]	No	None	Confirmed	This study	1.1; 1.3; 6.1; 8.1
34	Alicante	Río Mar (Pilar de la Horadada)	1–5	1.377	3.7 ± 1.53	Large[E]	No	None	Confirmed	This study	1.1; 1.3; 6.1
35	Nador	Barranco del Quemadero (Melilla)	100–110	36.908	2.4 ± 1.56	Large[E]	Yes	SCI	Confirmed	This study	2.2
36	Nador	Barranco del Nano (Melilla)	85–110	24.630	3.2 ± 1.04	Large[E]	Yes	SCI	Confirmed	This study	
Morocco											
37	Nador	Near Beni Chiker (Beni Chiker)	130–150	0.082		Small[C]	No	None	Confirmed	This study	2.2; 3.2; 9.4
38	Nador	Taxdirt–Cabo de Tres Forcas (Beni Chiker)	100–210	115.639	3.2 ± 1.56	Large[E]	Yes	None	Confirmed	This study	2.2; 3.2
39	Nador	Near Beni Sidel (Beni Sidel)	180–200	0.142		Small[C]	No	None	Confirmed	This study	2.2; 8.1
40	Nador	Road to Cap de Trois Fourches (Cap de Trois Fourches)	180–220	0.150	1.3 ± 0.70	Medium[E]	Yes	None	Confirmed	This study	4.1; 8.1
41	Nador	Douar Ighzar-n-Yamrabthan (Douar Ighzar-n-Yamrabthan)	42–67	0.090	1.5 ± 1.10	Medium[E]	Yes	None	Confirmed	This study	
42	Nador	Duar Izzemmouren (Ras Kebdana)	40–50	4.211	2.3 ± 1.20	Large[E]	Yes	None	Confirmed	This study	2.2; 2.3
43	Nador	Ras El Má (Ras Kebdana)	35–52	3.686	2.3 ± 1.01	Large[E]	No	None	Confirmed	This study	2.2; 9.4
44	Nador	Near Hidoun (Hidoun)							Not retrieved	This study	
45	Nador	Târia n Tît (Charrana)	30–52	0.540		Small[C]	No	None	Confirmed	This study	

Table 1 (*Cont.*)

No.	Country, region	Locality (municipality)	Altitudinal range (m)	Area (ha)	Mean density ± SD (plants/m²)	Population size[1]	Seedlings present	Protection[2]	Current status	Source	Threats
Algeria											
46	Oran	Cabo Lindlés (Aïn-El-Turk)	90						Extinct	Agulló et al. (2017)	
47	Oran	Cap Falcon (Aïn-El-Turk)	50						Extinct	Agulló et al. (2017)	
48	Oran	Aïn-El-Turk (Aïn-El-Turk)	75–80						Extinct	Agulló et al. (2017)	
49	Oran	Aïn-El-Kerma (Oran)	170			Small[C]		None	Confirmed	Agulló et al. (2017)	1.1; 1.3; 2.3; 6.1; 8.1; 9.4

[1]Determined by counting (superscript C) or estimating (superscript E) the total number of mature plants and categorizing as small (< 100 individuals), medium (101–2,000) or large (> 2,000) population.
[2]SCI, Site of community importance; PMR, Plant micro-reserve sensu Laguna et al. (2004); *protection only partially covers the population area.

extracted from the matrix projection model was 28.44 years (3 generations = 85.32 years; Sulis, 2016). Following the precautionary principle (IUCN, 2017), the smaller value of generation length (i.e. 15.97 years) was retained. Extinction risk was calculated considering three alternative assessments (10 years or three generations, 20 years or five generations, and 100 years). Quasi-extinction probabilities were calculated by 500 model iterations (van der Meer et al., 2014). Matrices were selected at random with replacement (each matrix had an equal probability of selection; Morris & Doak, 2002). A quasi-extinction threshold of 20 individuals was designated a priori, to help minimize the demographic stochasticity associated with small population size (Morris & Doak, 2002).

We also modelled three separate scenarios, one for each population size class, to examine extinction risk. We developed each model using the global stochastic growth rate ($\lambda s = 1$; Sulis, 2016; Sulis et al., 2018) and the effective population size.

Results

We located records of *H. caput-felis* in 49 localities along the western Mediterranean coasts, mainly in Spain (32 localities, including two in Melilla), followed by Morocco (nine localities), Italy and Algeria (four localities in each country; Table 1). We confirmed the presence of *H. caput-felis* in 41 localities, 40 of which we verified in the field, and one of which was documented in Agulló et al. (2017; no. 49 in Table 1). In two localities on the Balearic Islands (Cala Conta in Ibiza, Maioris in Majorca) and one in Morocco (near Hidoun, Nador), field surveys carried out by ourselves and other researchers failed to locate the species. Following a precautionary approach, we reported the species as 'not retrieved' in these localities. We were, however, able to confirm recent extinctions at two localities in Europe (Santa Pola in Spain, Seu in Italy) and three localities in Algeria.

All sites where occurrence was confirmed are in coastal environments, with the exception of one population in Morocco that is 3.44 km from the coast. The altitudinal range at which we located the species was 0–220 m. In Europe, we found the plant below 110 m, whereas in North Africa the species occurred in some cases above 150 m. The slope of localities is 0–45°. The area occupied by the species in each locality was variable, from 10 m² at Is Arutas in Sardinia to 116 and 101 ha at Taxdirt and Cap Blanc, respectively. Mean plant density was 3.19 ± SD 2.13 plants/m², varying from 1.10 ± SD 0.65 plants/m² (Cabo Cervera, Alicante) to 9.6 ± SD 1.85 plants/m² (Sa Ràpita, Majorca). Population size ranged from a few mature plants (Is Arutas, Cabras) to more than tens of thousands (Cap Blanc, Llucmajor). More than half of localities (56.1%) had a population size > 2,000 mature plants. The population size was ≤ 100 individuals in 26.8% of localities. The population structure was mainly characterized by reproductive

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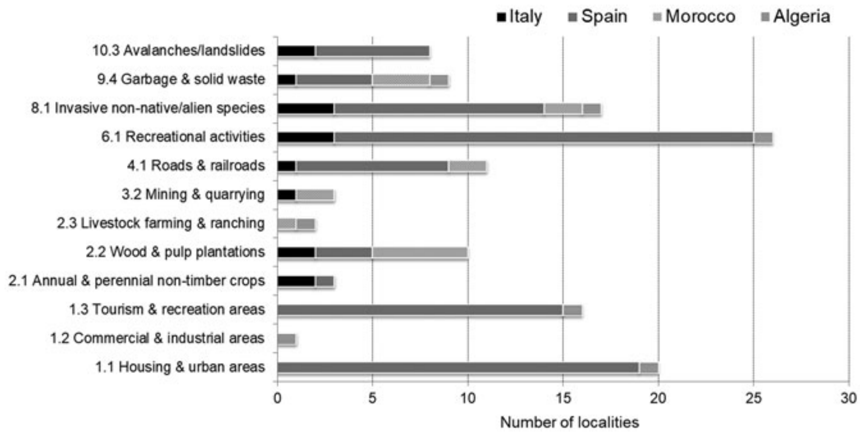

FIG. 1 Number of localities subject to each of the main threats (Table 1) to the rock rose *Helianthemum caput-felis* populations; data for Algeria was obtained from Agulló et al. (2017).

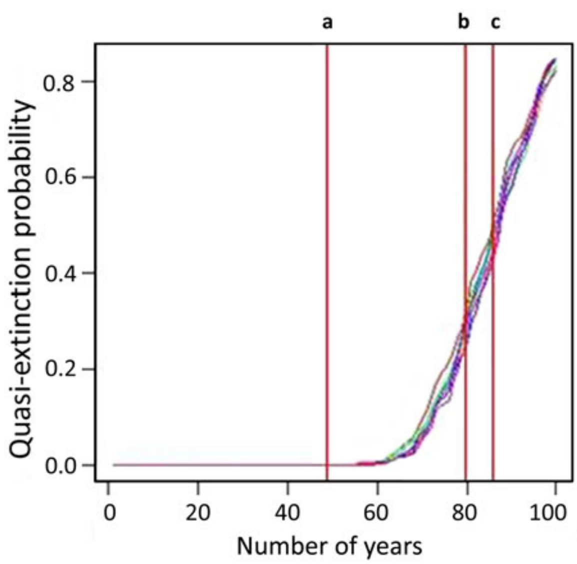

FIG. 2 Simulated cumulative distribution functions of the number of years for populations of *H. caput-felis* to reach a quasi-extinction threshold of 20 individuals: a, three generations (integral projection model); b, five generations (integral projection model); c, three generations based on generation time from the matrix population model. The lines are separate estimates of the cumulative distribution of extinction probabilities based on 500 iterations of population growth over 100 years (see Stubben & Milligan, 2007 for further details).

and juvenile plants (> 95%). Despite repeated surveys in the recruitment season, we observed seedlings in only 47.5% of localities, with recruitment absent in all small populations and in the 36.7% of medium and large populations (Table 1).

The main threats affecting the persistence of *H. caput-felis* populations are related to human activities (Fig. 1), including recreational activities (i.e. disturbance effects posed by recreation; 63.45% of localities), housing and urban areas (48.78%) and tourism and recreation (i.e. habitat effects of tourism and recreation sites with a substantial footprint; 39.00%). Other threats were invasive alien species (i.e. *Carpobrotus* sp., *Agave* sp., *Acacia* sp. and *Ricinus communis* L.; 41.46%), roads and railroads (26.83%), wood and pulp plantations (24.39%), and the presence of rubbish (IUCN threat classification 'garbage and solid waste'; 21.95%). In 26.66% of localities, all in Europe, avalanches or landslides appear to threaten the persistence of *H. caput-felis* (Fig. 1, Table 1).

According to the generation time extracted from the integral projection model, there was no extinction risk for three generations (Fig. 2), but there was an extinction probability of c. 30% for a five generation period (79.85 years; Fig. 2). Considering the generation time extracted from the matrix population model, the length of three generations was 85.31 years, which corresponded to a quasi-extinction risk of c. 45% (Fig. 2).

The quasi-extinction risk models for the three population size classes, considering each locality to be isolated, showed that seven small populations (< 50 plants) are likely to become extinct within the next 10 years, small populations with < 100 individuals had a quasi-risk extinction probability of 100% in 67 years, and medium populations had quasi-extinction probabilities of 20 and 100% in 100 and 160 years, respectively. Only large populations (> 2,000 individuals) are not at risk of extinction.

Conservation status assessment

Considering the mean distance between localities (392 km) and the results of the Delauney triangulation, the current EOO of *H. caput-felis*, including all confirmed localities, is 100,682 km^2 (Fig. 3), and the AOO is 168 km^2 (42 2 × 2 km cells). Since 1999 the extinction of *H. caput-felis* has been documented in five localities (Table 1). However, the reduction in EOO was negligible (0.007%) because these localities were within the convex polygon or close to the edge. However, AOO decreased by three cells (12 km^2), which gave a decline 6.67% since 1999. Such values do not reach the minimum threshold for threatened taxa under Red List criterion A.

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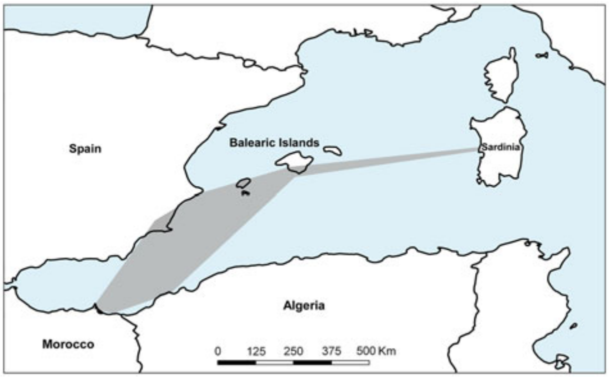

FIG. 3 Extent of Occurrence (EOO) calculated for *H. caput-felis*.

Under Red List criterion B the species distribution has 'severe fragmentation' (sensu IUCN, 2017). Our quantitative models indicate c. 46% of confirmed localities (eight medium and 11 small populations) are below the viability threshold and therefore could be prone to extinction, close to the 50% threshold for 'severe fragmentation'. The Red List guidelines recommend integrating this evaluation with a species' biological traits, in particular dispersal ability. A population genetic study in the Alicante (the core of the species range, on the Iberian Peninsula), Melilla (North Africa) and Balearic Islands localities, indicated significant genetic divergence, which would indicate genetic isolation and limited gene flow among these populations (Agulló et al., 2011), suggesting that localities separated by longer distances (i.e. those in Algeria and Sardinia) may be functionally isolated. Taken together, these findings suggest the species is severely fragmented. *Helianthemum caput-felis* could therefore be categorized as Endangered based on B2ab(ii, iii, iv, v); i.e. its small AOO (2), highly fragmented distribution (a) and calculated/observed decline (b) in AOO (ii), habitat quality (iii), number of localities (iv) and number of mature plants (v).

Helianthemum caput-felis could also be categorized as Endangered under criterion E as a result of a quasi-extinction risk probability of c. 30% in five generations (79.85 years based on the integral projection model) and c. 45% in three generations (85.32 years based on the matrix population model).

Discussion

Although many countries are contracting parties to international conventions and other international regulations, such as the European Habitat Directive, that encourage monitoring and protection of wild flora, global protection remains insufficient, with c. 13% of known vascular plant species threatened with extinction (Royal Botanic Gardens, 2016). Moreover, the number of global species assessments, as required by the targets of the Global Strategy for Plant Conservation and the CBD, is low, and such assessments particularly challenging when a species occurs in several countries. We believe that our research presented here is the first global assessment of the range and conservation status of *H. caput-felis.*

The distribution of *H. caput-felis* is concentrated in the westernmost Mediterranean Basin along the eastern Iberian coasts, reaching its easternmost limit in Su Tingiosu (Italy), northernmost in Capo Mannu (Italy), westernmost in Beni Chiker and southernmost in Beni Sidel (both in Morocco). The status of the species in North Africa remains unclear, however. In three Algerian localities where occurrence was documented by recent herbarium specimens Agulló et al. (2017) were unable to confirm presence but did locate the species in a previously undocumented locality. The species' status also requires clarification in Morocco, where we could not confirm presence in one previously documented locality. Considering that this species can grow in locations that may be difficult to explore (e.g. vertical coastal cliffs, sandy and fossil dunes, inland ravines), additional surveys are needed.

Our global assessment of *H. caput-felis* as Endangered is consistent with previous regional assessments (Agulló et al., 2010, 2017; Bilz et al., 2011; Fenu et al., 2015b; Rossi et al., 2016) based only on distribution data (i.e. criterion B). Assessments based on geographical data are the most common for plants, because distribution data are the easiest to obtain. However, our integration of criteria B and E provides a more complete conservation assessment. In addition, the absence of seedling recruitment and the high juvenile mortality rate recorded in several localities were further negative indicators (Sulis, 2016; Sulis et al., 2018). The null or limited recruitment rate in some populations could be partially explained by the effect of drought during 2013–2017 in eastern Spain (García de la Serrana et al., 2015; Laguna & Ferrer, 2016).

A combination of some recent extinction events and the fact that we were unable to relocate the species at some previously documented locations indicates that the AOO of *H. caput-felis* is contracting, probably as a result of continuing loss of habitat quality and reproductive individuals. Habitat reduction and degradation appear to be mainly a result of the expansion of infrastructure, a key element in biodiversity loss (e.g. Newbold et al., 2015). In particular, as described for several Mediterranean plant species (e.g. Fenu et al., 2011; Ballantyne & Pickering, 2013; Fois et al., 2018; Orsenigo et al., 2018), the main threats to *H. caput-felis* are related to the degradation of the species' habitat from tourism and recreational activities and the expansion of housing and urban areas. Both the Spanish (Giménez et al., 2008; Agulló et al., 2010; Marco et al., 2011, 2016; Zaragozí et al., 2012) and Algerian (Agulló et al., 2017) coasts have experienced extensive urban development linked to tourism. We did not find that climate change, although a major driver of species extinctions (Gómez et al., 2015; Fenu et al., 2017; Orsenigo et al., 2018), is a threat to *H. caput-felis* but this could be because of the difficulty of detecting its effects (Fenu et al., 2017). However, the long-term

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consequences of climate change, especially drought or irregular rainfall, need to be considered for coastal plants such as *H. caput-felis* (García de la Serrana et al., 2015; Laguna & Ferrer, 2016).

Although several populations of *H. caput-felis* (c. 41% of all localities and c. 62.5% of those in Europe) are currently protected (i.e. within a Site of community importance and/or Plant micro-reserve), our findings nevertheless indicate that *H. caput-felis* faces a substantial risk of extinction over the short to medium term in the absence of additional management actions. As demonstrated for other species (e.g. Aguilella et al., 2010; Rossi et al., 2016; Fenu et al., 2017), our data indicate that current legal protection and passive conservation measures are insufficient to guarantee the persistence of *H. caput-felis*. This is contrary to EU legislation, which states that conservation of this species is mandatory and that member states are responsible for its conservation.

Helianthemum caput-felis requires a transnational conservation strategy focusing on protection of each locality in which it occurs, to avoid further decline or extinctions, habitat restoration in degraded localities, mainly in Spain and Algeria, and reduction of the impacts of recreational activities and urban sprawl. Furthermore, as already underway in Melilla (M. Tapia, pers. comm.), translocations could be carried out in suitable areas and reintroductions at sites from which the species has recently disappeared. Previous experiences with threatened Mediterranean coastal plants have demonstrated that these activities would be low-cost projects with good chance of success (e.g. Cogoni et al., 2013; Fenu et al., 2016; Laguna et al., 2016). Finally, monitoring is required of all known localities in which the species persists. Although it could be challenging to sustain long-term monitoring, it is fundamental for assessment of conservation status and for effective local conservation.

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Conflicts of interest None.

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

References

Aguilella, A., Fos, S. & Laguna, E. (2010) *Catálogo Valenciano de Especies Amenazadas de Flora*. Conselleria de Medi Ambient, Aigua, Urbanisme i Habitatge. Generalitat Valenciana, Valencia, Spain.

Agulló, J.C., Juan, A., Alonso, M.Á. & Crespo, M.B. (2010) *Helianthemum caput-felis* Boiss. In *Atlas y Libro Rojo de la Flora Vascular Amenazada de España. Adenda 2010. Dirección General de Medio Natural y Política Forestal (Ministerio de Medio Ambiente, y Medio Rural y Marino)—Sociedad Española de Biología de la Conservación de Plantas* (eds Á. Bañares, G. Blanca, J. Güemes, J.C. Moreno & S. Ortiz), pp. 76–77. Ministerio de Medio Ambiente, y Medio Rural y Marino, y Sociedad Española de Biología de la Conservación de Plantas, Madrid, Spain.

Agulló, J.C., Juan, A., Crespo, M.B., Alonso, M.Á. & Terrones, A. (2017) An updated report on the distribution and conservation status of the Endangered cat's head rockrose *Helianthemum caput-felis* (Magnoliopsida: Violales: Cistaceae) in Algeria. *Journal of Threatened Taxa*, 9, 9885–9891.

Agulló, J.C., Juan, A., Guilló, A., Alonso, M.Á. & Crespo, M.B. (2011) Genetic diversity and phylogeographical assessment of *Helianthemum caput-felis* Boiss. (Cistaceae) based on AFLP markers. *Fitosociologia*, 48, 21–29.

Ballantyne, M. & Pickering, C.M. (2013) Tourism and recreation: a common threat to IUCN red-listed vascular plants in Europe. *Biodiversity and Conservation*, 22, 3027–3044.

Balmford, A., Bennun, L., ten Brink, B., Cooper, D, Côté, I.M, Crane, P. et al. (2005) The Convention on Biological Diversity's 2010 target. *Science*, 307, 212–213.

Beresford, A.E., Buchanan, G.M., Sanderson, F.J., Jefferson, R. & Donald, P.F. (2016) The contributions of the EU nature directives to the CBD and other multilateral environmental agreements. *Conservation Letters*, 9, 479–488.

Bilz, M., Kell, S.P., Maxted, N. & Lansdown, R.V. (2011) *European Red List of Vascular Plants*. Publications Office of the European Union, Luxembourg, Luxembourg.

Burgman, M.A. & Fox, J.C. (2003) Bias in species range estimates from minimum convex polygons: implications for conservation and options for improved planning. *Animal Conservation*, 6, 19–28.

Butchart, S.H.M., Walpole, M., Collen, B., van Strien, A., Scharlemann, J.P.W., Almond, R.E.A. et al. (2010) Global biodiversity: indicators of recent declines. *Science*, 328, 1164–1168.

Ceballos, G., Ehrlich, P.R., Barnosky, A.D., García, A., Pringle, R.M. & Palmer, T.M. (2015) Accelerated modern human-induced species losses: entering the sixth mass extinction. *Science Advances*, 1, e1400253.

Cogoni, D., Fenu, G., Concas, E. & Bacchetta, G. (2013) The effectiveness of plant conservation measures: the *Dianthus morisianus* reintroduction. *Oryx*, 47, 203–206.

Collen, B., Dulvy, N.K., Gaston, K.J., Gärdenfors, U., Keith, D.A., Punt, A.E. et al. (2016) Clarifying misconceptions of extinction risk assessment with the IUCN Red List. *Biological Letters* 12, 20150843.

European Commission (1992) *Council Directive 92/43/EEC of 21 May 1992 on the Conservation of Natural Habitats and of Wild Fauna and Flora*. The Council of the European Communities, Brussels, Belgium.

Fenu, G., Bacchetta, G., Giacanelli, V., Gargano, D., Montagnani, C., Orsenigo, S. et al. (2017) Conserving plant diversity in Europe: outcomes, criticisms and perspectives of the Habitats Directive application in Italy. *Biodiversity and Conservation* 26, 309–328.

Fenu, G., Cogoni, D. & Bacchetta, G. (2016) The role of fencing in the success of threatened plant species translocation. *Plant Ecology*, 217, 207–217.

Fenu, G., Cogoni, D., Pinna, M.S. & Bacchetta, G. (2015a) Threatened Sardinian vascular flora: a synthesis of 10 years of monitoring activities. *Plant Biosystems*, 149, 473–482.

Fenu, G., Cogoni, D., Sulis, E. & Bacchetta, G. (2015b) Ecological response to human trampling and conservation status of

https://doi.org/10.1017/S0030605318001424 Published online by Cambridge University Press

Helianthemum caput-felis (Cistaceae) at the eastern periphery of its range. *Botany Letters* 162, 191–201.

Fenu, G., Mattana, E. & Bacchetta, G. (2011) Distribution, status and conservation of a Critically Endangered, extremely narrow endemic: *Lamyropsis microcephala* (Asteraceae) in Sardinia. *Oryx*, 45, 180–186.

Fois, M., Bacchetta, G., Cuena-Lombraña, A., Cogoni, D., Pinna, M.S, Sulis, E. & Fenu, G. (2018) Using extinctions in species distribution models to evaluate and predict threats: a contribution to plant conservation planning on the island of Sardinia. *Environmental Conservation*, 45, 11–19.

García de la Serrana, R., Vilagrosa, A. & Alloza, J.A. (2015) Pine mortality in southeast Spain after an extreme dry and warm year: interactions among drought stress, carbohydrates and bark beetle attacks. *Trees*, 29, 1791–1804.

Gargano, D., Fenu, G., Medagli, P., Sciandrello, S. & Bernardo, L. (2007) The status of *Sarcopoterium spinosum* (Rosaceae) at the western periphery of its range: ecological constraints lead to conservation concerns. *Israel Journal of Plant Sciences*, 55, 1–13.

Giménez, P., Sánchez, A., Padilla, A. & Marco, J.A. (2008) Integración de una cartografía corológica a escala de detalle mediante GPS en el proceso urbanizador: *Halianthemum caput-felis* Boiss. en el litoral sur de Alicante (España). In *La Perspectiva Geográfica ante los retos de la Sociedad y el Medio Ambiente en el Contexto Ibérico—Ponencias XI Coloquio Ibérico de Geografía* (eds J. Bosque & V. Rodríguez-Espinosa), pp. 1–15. Universidad de Alcalá de Henares, Madrid, Spain.

Gómez, J.M., González-Megías, A., Lorite, J., Abdelaziz, M. & Perfectti, F. (2015) The silent extinction: climate change and the potential hybridization-mediated extinction of endemic high-mountain plants. *Biodiversity and Conservation*, 24, 1843–1857.

GSPC (Global Strategy For Plant Conservation) (2008) Http://www.cbd.int/gspc [accessed 20 October 2017].

IUCN (2001) *IUCN Red List Categories and Criteria v 3.1*. IUCN Species Survival Commission Gland, Switzerland and Cambridge, UK, IUCN Species Survival Commission. Http://www.iucnredlist.org/technical-documents/categories-and-criteria [accessed 20 July 2017].

IUCN (2012a) *IUCN Red List Categories and Criteria v. 3.1*. 2nd edition. IUCN Species Survival Commission, Gland, Switzerland. Https://www.iucnredlist.org/resources/categories-and-criteria [accessed 20 September 2017].

IUCN (2012b) *Threats Classification Scheme v. 3.2*. Http://www.iucnredlist.org/technical-documents/classification-schemes/threats-classification-scheme [accessed 28 August 2017].

IUCN (2017) *Standards and Petitions Subcommittee Guidelines for Using the IUCN Red List Categories and Criteria v.13*. Prepared by the Standards and Petitions Subcommittee. Http://www.iucnredlist.org/documents/RedListGuidelines.pdf [accessed 12 December 2017].

Laguna, E., Deltoro, V.I., Pérez-Botella, J., Pérez-Rovira, P., Serra, L., Olivares, A. & Fabregat, C. (2004) The role of small reserves in plant conservation in a region of high diversity in eastern Spain. *Biological Conservation*, 119, 421–426.

Laguna, E. & Ferrer, P.P. (2016) Global environmental changes in an unique flora: endangered plant communities in the Valencia region. *Mètode Science Studies Journal*, 6, 36–45.

Laguna, E., Navarro, A., Pérez-Rovira, P., Ferrando, I. & Ferrer-Gallego, P.P. (2016) Translocation of *Limonium perplexum* (Plumbaginaceae), a threatened coastal endemic. *Plant Ecology*, 217, 1183–1194.

Mace, G.M., Collar, N.J., Gaston, K.J., Hilton-Taylor, C., Akçakaya, H.R., Leader-Williams, N. & Stuart, S.N. (2008) Quantification of extinction risk: IUCN's system for classifying threatened species. *Conservation Biology*, 22, 1424–1442.

Marco, J.A., Giménez, P., Padilla, A. & Sánchez, A. (2011) Crecimiento urbano y extinción de flora rara: aplicaciones cartográficas en el caso de *Helianthemum caput-felis* Boiss. *Serie Geográfica*, 17, 125–139.

Marco, J.A., Giménez, P., Padilla, A. & Sánchez, A. (2016) Cartografía corológica y área de ocupación de Helianthemum caput-felis Boiss. en la Península Ibérica. In *Avances en Biogeografía. Áreas de Distribución: Entre Puentes y Barreras* (eds J. Gómez Zotano, J. Arias, J.A. Olmedo & J.L. Serrano), pp. 108–116. Tundra Ediciones & Editorial Universidad de Granada, Almenara & Granada, Spain.

Morris, W.F. & Doak, D.F. (2002) *Quantitative Conservation Biology: the Theory and Practice of Population Viability Analysis*. Sinauer, Sunderland, USA.

Newbold, T., Hudson, L.N., Hill, S.L., Contu, S., Lysenko, I., Senior, R.A. et al. (2015) Global effects of land use on local terrestrial biodiversity. *Nature*, 520, 45–50.

Orsenigo, S., Montagnani, C., Fenu, G., Gargano, D., Peruzzi, L., Abeli, T. et al. (2018) Red Listing plants under full national responsibility: extinction risk and threats in the vascular flora endemic to Italy. *Biological Conservation*, 224, 213–222.

Pimm, S.L., Jenkins, C.N., Abell, R., Brooks, T.M., Gittleman, J.L., Joppa, L.N. et al. (2014) The biodiversity of species and their rates of extinction, distribution, and protection. *Science*, 344, 1246752.

Pimm, S.L., Russel, G.J., Gittleman, J.L. & Brooks, T.M. (1995) The future of biodiversity. *Science*, 269, 347–350.

Pullin, A.S., Baldi, A., Can, O.E., Dieterich, M., Kati, V., Livoreil, B. et al. (2009) Conservation focus on Europe: major conservation policy issues that need to be informed by conservation science. *Conservation Biology*, 23, 818–824.

R Core Team (2014) *R: a Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. Http://www.R-project.org [accessed 8 May 2017].

Rodrigues, A.S., Pilgrim, J.D., Lamoreux, J.F., Hoffmann, M. & Brooks, T.M. (2006) The value of the IUCN Red List for conservation. *Trends in Ecology and Evolution*, 21, 71–76.

Rossi, G., Orsenigo, S., Montagnani, C., Fenu, G., Gargano, D., Peruzzi, L. et al. (2016) Is legal protection sufficient to ensure plant conservation? The Italian Red List of policy species as a case study. *Oryx*, 50, 431–436.

Royal Botanic Gardens (2016) *The State of the World's Plants*. Royal Botanic Gardens, Kew, UK.

Serra, L., Fabregat, C., Herrero-Borgoñón, J. & López Udias, S. (2000) *Distribución de la Flora Vascular Endémica, Rara o Amenazada en la Comunidad Valenciana*. Colección Biodiversidad, Generalitat Valenciana, Spain.

Stubben, C. & Milligan, B. (2007) Estimating and analyzing demographic models using the *popbio* package in *R. Journal of Statistical Software*, 22, 1–23.

Sulis, E. (2016) *Ecological features, populations traits and conservation status of* Helianthemum caput-felis *along its distribution range*. PhD thesis. University of Cagliari, Cagliari, Italy.

Sulis, E., Bacchetta, G., Cogoni, D. & Fenu, G. (2018) Short-term population dynamics of *Helianthemum caput-felis*, a perennial Mediterranean coastal plant: a key element for an effective conservation programme. *Systematics and Biodiversity*, 16, 774–783.

van der Meer, S., Dahlgren, J.P., Mildén, M. & Ehrlén, J. (2014) Differential effects of abandonment on the demography of the grassland perennial *Succisa pratensis*. *Population Ecology*, 56, 151–160.

Zaragozí, B., Giménez, P., Navarro, J.T., Dong, P. & Ramón, A. (2012) Development of free and open source GIS software for cartographic generalisation and occupancy area calculations. *Ecological Informatics*, 8, 48–54.

https://doi.org/10.1017/S0030605318001424 Published online by Cambridge University Press