Article

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Giuseppe Caruso & Giulia Montepaone

Geographic distribution and population composition of *Ephedra fragilis* (*Ephedraceae*) in continental Italy

Abstract

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Ephedra fragilis is a very rare plant in peninsular Italy. The only formerly known locality of this species is located at San Ferdinando, Calabria. The present survey, extended to 60 coastal and subcoastal localities of central-southern Italy, re-found and re-evaluated the conservation status (which resulted improved) of the already known locality of the studied species and found a new locality at Capo Bruzzano, Calabria. Unfortunately, in spite of the wide investigated area, the survey didn't find any new population outside the Calabrian territory.

Key words: conservation, coastal habitats, Calabria.

Introduction

The genus *Ephedra* L. (*Ephedraceae*) includes about 60 species living in arid environments distributed across the Mediterranean region, C-Asia, NW-America, Mexico, S-Andes and Patagonia (Meusel & al. 1965; do Amaral Franco 1986). In Europe, during glacial ages, implying xeric conditions, the genus reached its maximum expansion (Elenga & al. 2000). In the Italian vascular flora, *Ephedra*, according to Pignatti (2017), counts 8 taxa: *E. fragilis* Desf., *E. foemina* Forsk., *E. nebrodensis* Tineo in Guss., *E. distachya* L., *E. podostylax* Boiss., *E. dubia* Boiss., *E. helvetica* C.A. Mey. and *E. negrii* Nouviant.

E. fragilis Desf., described from North Africa (Desfontaines 1799), is a dioecious taxon, showing a W-Steno-Mediterranean distribution (Pignatti 2017), with also Macaronesian disjunctions (do Amaral Franco 1986). The autoecology of *E. fragilis* is linked to thermomediterranean, dry, sandy or rocky habitats, both along the sea coastline and near inland up to 300 m a.s.l. (Bell & Bachman 2011). According to Bell & Bachman (2011) the conservation status of this taxon is LC (Least Concern) at European level.

In Italy, while the occurrence of *E. fragilis* is well documented for Sicily (Giardina & al. 2007), the presence of this taxon on continental Italy has always been quite controversial. No recent record for this taxon is known (or confirmed) for the Italian peninsula. Although Calabria has recently recorded an increased number of published studies on native and inva-

sive alien species (among the most recent: Spampinato & al. 2017, 2018, 2019; Maiorca & al. 2020; Maruca & al. 2019; Musarella & al. 2019, 2020; Musarella 2020; Rosati & al. 2020), very few are the records of *E. fragilis* in the southernmost administrative region of continental Italy (Caruso & al. 2009, 2010b, 2012; Pignatti 2017). Due to Calabria geographical proximity to Sicily, the ecological similarities of these regions (especially coastal and subcoastal areas), as well as the formerly recorded occurrence of *E. fragilis* in this territory, although other continental administrative regions of Italy have been surveyed; Calabria has been considered the focus area for the purpose of this research.

Macrobioclimate of CS-Italy, according to Rivas-Martinez & Rivas-Saenz (1996-2019) bioclimatic classification system, and to the bioclimatic classification of Italian territory proposed by GIS Natura (Ministero dell'ambiente e della tutela del territorio, Direzione per la protezione della Natura, Politecnico di Milano 2005) is mostly Mediterranean along the coast and Temperate in the inland with the increasing altitude. Temperate macrobioclimate occurs on the Tyrrhenian coast from northern third of Tuscany, while on Adriatic coast from the northern half of Abruzzo. Ombrotype of the study area is mainly subhumid, and locally is dry in N-Calabria, E-Basilicata and most of the Apulian territory; the hyperhumid ombrotype is confined to the mountain areas. Thermotype is thermo-Mediterranean on the coastal areas of the southern sector of the studied area; going up on the Apennine range it becomes gradually meso-Mediterranean, supra-Mediterranean and supra-temperate. Other recent interpretations of the bioclimate of Italy, such as those provided by Pesaresi & al. (2014, 2017), despite well argumented, provide a more restricted interpretation of the thermo-Mediterranean belt, not suitable for our analysis. Anyway, most of the investigated stands (except those from 001 to 007) are encompassed by the thermo-Mediterranean belt as designed by Pesaresi & al. (2014, 2017).

In Calabria, *E. fragilis* has been historically recorded many times (Porta 1879; Fiori 1923-25; Chiarugi 1956; Zangheri 1976; Pignatti 1982; Géhu & al. 1984) but always confused with *Ephedra distachya* as shown by Caruso & al. (2012). In fact, Brullo & al. (2001) and Spampinato (2014) reported for Southern Calabria only *E. distachya* subsp. *distachya*. More recent data on Calabria vascular flora (Bernardo & al. 2011), based on field and herbaria surveys (Caruso & al. 2009, 2010, 2012) better defined the species distribution. Flora d'Italia (Pignatti 2017) based the treatment of *Ephedraceae* on Nouviant (1996, 1997a, 1997b, 1998a, 1998b) without the detailed data provided by Caruso & al. (2009, 2010b, 2012). Anyway, Pignatti (2017) confirms the occurrence of *E. fragilis* in Calabria, as well as Bartolucci & al. (2018), while both of them do exclude the occurrence of the investigated species in other continental regions of the Italian Peninsula. Calabria, a peninsula surrounded by 740 km of coasts, shows important differences between Tyrrhenian (mostly rocky) and Ionian (mostly sandy) coast (Regione Calabria 2001) often more or less environmentally modified (Biondi & al. 1996; Niccoli & Procopio 1995; Veltri & al. 2000; Regione Calabria 2001).

Aim of this work is to investigate and map, on reliable literature data and field research, the geographical distribution of *E. fragilis* in continental Italy, and provide updated information on the quantitative, distributive and ecological data, and on the conservation status of this rare species in the surveyed area.

Methods

Geographical distribution - The survey has been based on literature and field data. Field investigation (2010-2019) has been addressed to verify and update data from literature, as well as to seek new formerly unknown stands of *Ephedra fragilis*. Being Central-Southern Italy a quite huge study area, the autoecology of the investigated species has been considered in order to focus more restricted areas to be studied. Central Italy conventionally encompasses the region Tuscany, Latium, Umbria and Marche, while Southern Italy encompasses Abruzzo, Molise, Apulia, Basilicata, Campania and Calabria. Inside this wide territory, only those sectors compatible with the ecology of the investigated species have been taken in account in order to select the areas deserving further field survey. Altitudinal range 0-300 m a.s.l., short distance by the sea coast, thermo-Mediterranean thermotype, have been considered to select the suitable areas. Data on thermotypes has been provided by a shape file included into GIS Natura 2.0 DVD (Ministero dell'ambiente e della tutela del territorio, Direzione per la protezione della Natura, Politecnico di Milano 2005). A preliminary GIS analysis, performed with QGIS software excluded Tuscany, Abruzzo, Molise (no thermo-Mediterranean areas) and Umbria (no sea coast, no thermo-Mediterranean thermotype) from survey. Where the species occurs the single plants (at least those appearing physically separated by other plants) of the target species have been geo-referenced by a GPS device (Garmin Montana 615t) and specimen identification has been performed by Flora d'Italia (Pignatti 2017) and Flora Europaea (Markgraf 1964), while nomenclature of floristic surveys follows Bartolucci & al. (2018) and, for alien taxa Galasso & al. (2018). Screened data have been organized as a geographical database and outputted as maps representing the general and local distribution of the species.

As shown in Fig. 1 and in the Electronic Supplementary File 1 (ESF1) the total investigated locations are 60, mostly located in Calabria (41), in Basilicata (5), Campania (5) Latium (5) and Apulia (4).

Population structure analysis – The continental sub-population of the studied species has been registered and mapped. The formerly known Tyrrhenian location has been here treated as two different subpopulations, because artificially divided in two different sectors by some human infrastructures, but in the past probably part of a unique coastal dune system. Each single individual has been georeferenced, measured (height, occupied area) and other information has been collected: geology, altitude, sex (dioecious species), slope and orientation.

Results

Geographic distribution - The field work produced no positive results in the investigated 19 localities across Latium, Campania, Basilicata and Apulia, while 3 of the 41 localities surveyed in Calabria showed the occurrence of *E. fragilis*. Localities CAL012 and CAL013, already known from literature (Caruso & al. 2012) but formerly reported as a single population, are located at San Ferdinando N #1 and #2 (San Ferdinando municipality, Reggio Calabria province) on the Tyrrhenian coast. Stand CAL024, before the present survey totally unknown, is located at Capo Bruzzano (Bianco municipality, Reggio Calabria province) on the Ionian coast of Calabria (Fig. 2).

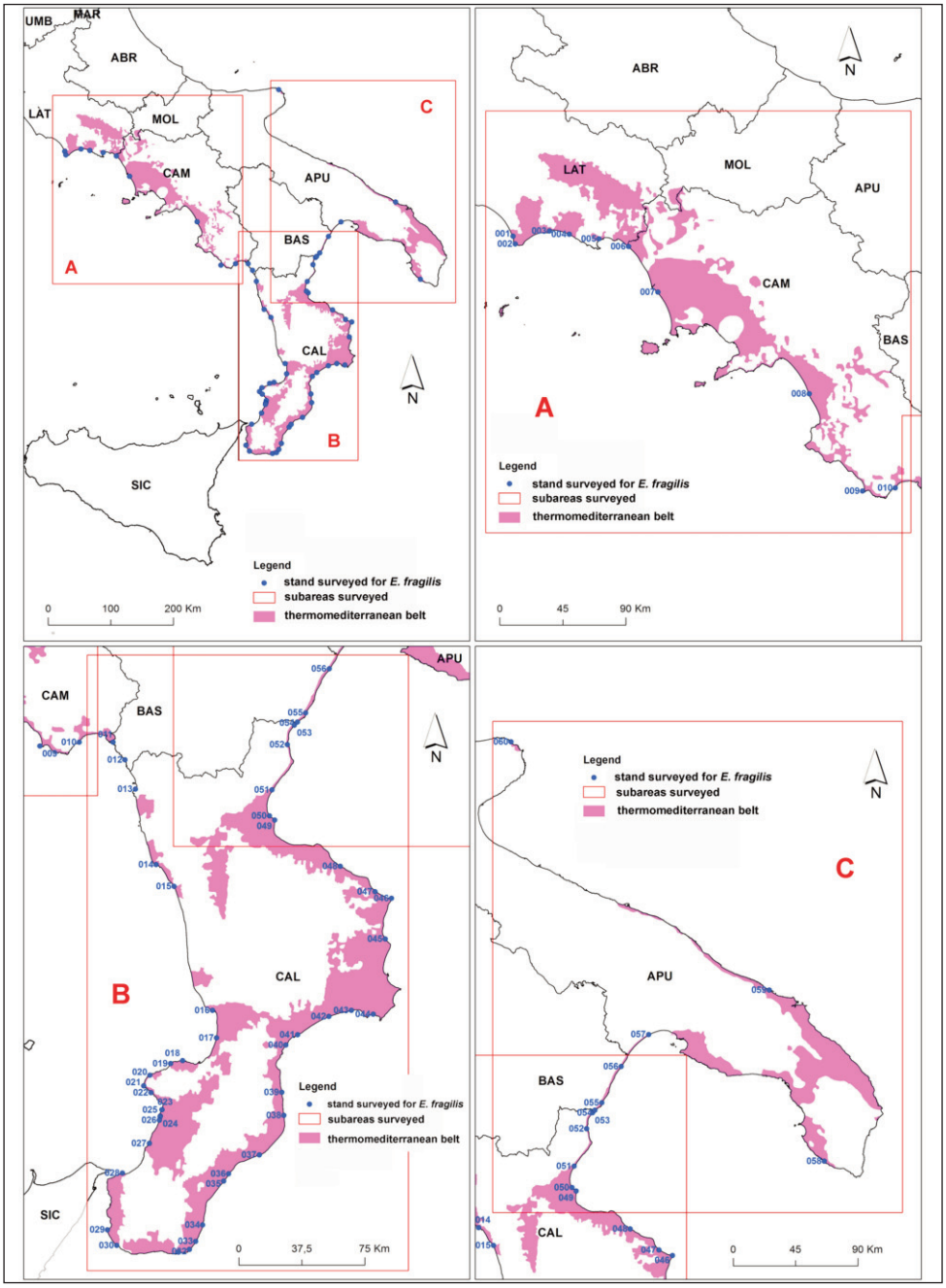

Fig. 1. Study area (Central-Southern Italy) and localities (blue dots) investigated in Latium, Campania, Basilicata, Calabria and Apulia administrative regions as part of this survey on *Ephedra fragilis*. The scale changes in different figures; the fuchsia color shows the thermo-Mediterranean thermotype belt.

Population survey – From the census of the continental sub-population of *E. fragilis* resulted the main group of plants occurs on the Tyrrhenian stands. Plants belonging to the investigated species in the area show three main different morphologies: young individuals, both coming from seed (generally well isolated, 2-5 m, from adult individuals) or from vegetative multiplication (often closer, 1-2 m, to the mother-plant), are less than 1 m high and usually cover an area 1 m^2 wide. Growing up, these individuals tend to cover a wider surface (circa 2-10 m^2) creeping away from the plant base, but they rarely increase their height over 2 m from soil. When in the immediate vicinity of the plant there is a shrub or a small tree *E. fragilis* behaves as a climbing vine, using these support-species as a tool to gain height (probably advantageous in seed dispersal) up to 4 m. Not uncommon are individuals (2-6) growing so close each other to be practically impossible to consider as isolated individuals (subunits; Tab. 1). Comparing the collected new data (Tab. 1) with those formerly available (Caruso & al. 2012) the stands (formerly treated as one biogeographic unit) increased from 17 to 36 individuals. Males are still 2, but females had grown from 4 to 8, while vegetative individuals from 11 to 26. The field survey found a formerly completely unknown new stand of *E. fragilis*. This sub-population counts 2 plants, supposedly young, with no apparent sex (due to absence of reproductive organs) (Fig. 3).

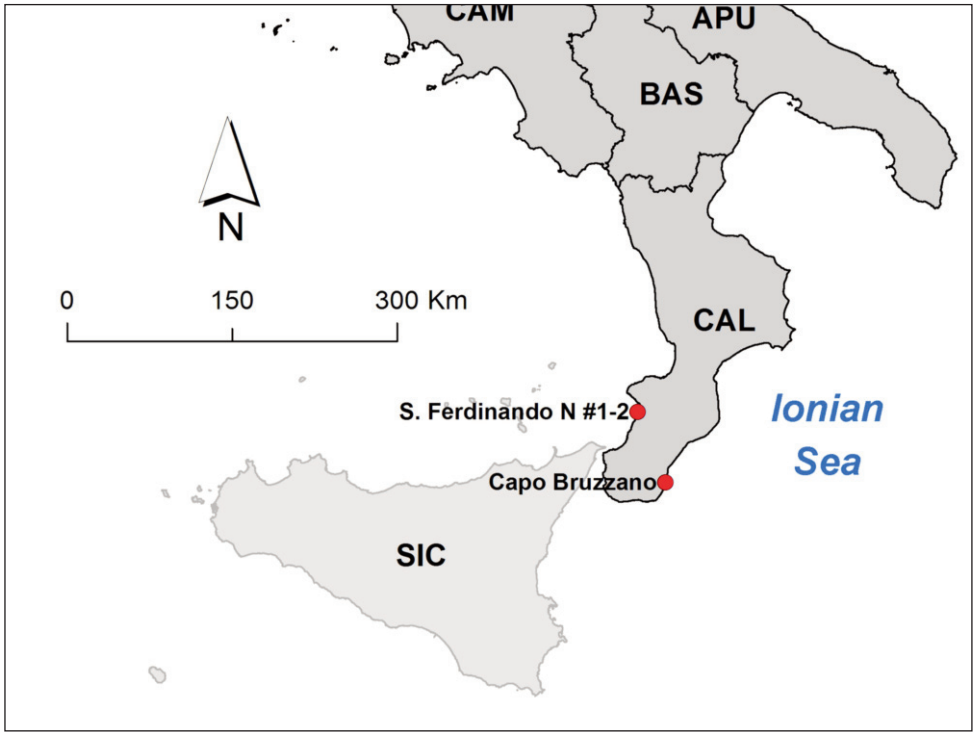

Fig. 2. Distribution of the localities (red dots) with *Ephedra fragilis* on continental Italy. Stands located at S. Ferdinando are difficult to distinguish each other (here represented by just one red dot) because at this scale symbols tend to overlap.

Table 1. Continental Italian population of *Ephedra fragilis*. Sex: V = vegetative; F = female; M = male; S = sand; SCH = schist; Geol. = geology; Area (in m^2): H = height in *m* (from soil); SUBUNITS = individuals forming the unit (counted as a single individual); SLOPE = inclination of the hillside (in sexagesimal degrees); Aspect = orientation of the hillside.

NR	SEX	LAT	LONG	ALT	GEOL.	AREA	H	SUBUNITS	SLOPE	ASPECT
CAL012-001	V	38° 29.73'N	15° 55.03'E	7	S	1	1	1	-	-
CAL012-002	V	38° 29.72'N	15° 55.03'E	7	S	14	2	1	-	-
CAL012-003	V	38° 29.71'N	15° 55.02'E	7	S	1	1	2	-	-
CAL012-004	F	38° 29.71'N	15° 55.03'E	7	S	3	1,5	1	-	-
CAL012-005	F	38° 29.71'N	15° 55.02'E	7	S	27	4	3	-	-
CAL012-006	V	38° 29.71'N	15° 55.04'E	7	S	10	2	2	-	-
CAL012-007	F	38° 29.71'N	15° 55.05'E	7	S	10	1	1	-	-
CAL012-008	V	38° 29.71'N	15° 55.04'E	7	S	1	1	1	-	-
CAL012-009	F	38° 29.70'N	15° 55.05'E	7	S	11	2	1	-	-
CAL012-010	M	38° 29.70'N	15° 55.02'E	7	S	6	1,5	1	-	-
CAL012-011	M	38° 29.68'N	15° 55.01'E	7	S	5	1,5	1	-	-
CAL013-001	V	38° 29.58'N	15° 55.00'E	7	S	2	1	1	-	-
CAL013-002	V	38° 29.58'N	15° 55.00'E	7	S	1	1	1	-	-
CAL013-003	V	38° 29.58'N	15° 55.33'E	7	S	12	1	1	-	-
CAL013-004	V	38° 29.57'N	15° 55.33'E	7	S	1,5	1	1	-	-
CAL013-005	F	38° 29.57'N	15° 55.01'E	7	S	2	1	1	-	-
CAL013-006	F	38° 29.57'N	15° 55.00'E	7	S	3,5	1	1	-	-
CAL013-007	V	38° 29.56'N	15° 55.03'E	7	S	2	1	1	-	-
CAL013-008	V	38° 29.56'N	15° 55.00'E	7	S	1	1	1	-	-
CAL013-009	V	38° 29.55'N	15° 55.00'E	7	S	6	1	1	-	-
CAL013-010	V	38° 29.54'N	15° 54.99'E	7	S	27	2	6	-	-
CAL013-011	V	38° 29.54'N	15° 55.02'E	7	S	13	4	5	-	-
CAL013-012	V	38° 29.52'N	15° 55.01'E	7	S	3	2	1	-	-
CAL022-001	V	38° 2.73'N	16° 8.64'E	30	SCH	1	1	1	45	SW
CAL022-002	V	38° 2.34'N	16° 8.64'E	40	SCH	1	1	1	45	SW
					TOT.	**165**		**38**		

Ecology and conservation – E. fragilis in absence of anthropic disturb successfully colonizes that flat sandy plain representing the highly altered remains of a coastal dune system. As written above, the number of plants has increased, and these numbers, quite modest in absolute terms, are, however, very important in a conservation perspective. The increasing number of plants demonstrate the ability of this species to colonize a so hostile environment and, above all, the positive trend of the local population, the unique formerly known stand of this very rare plant on continental Italy. This positive conservative outcome is mainly due to the actions wanted by the municipality administration that turned the abandoned area into a sub-urban park freely available for jogging and cycling, and, of course, colonizing plants. It's not clear if S. Ferdinando municipality was aware of the occurrence in the area of plants deserving conservation measures such as *E. fragilis* and the rare endemic *Retama raetam* subsp. *gussonei* (Webb) Greuter (*Fabaceae*) (Caruso & al. 2010a). Anyway, due to the inaccessibility to cars, plants had the opportunity to occupy, along the years, an increasing surface relatively undisturbed. The habitat is characterized by the occurrence of psammophilous taxa such as *Achillea maritima* (L.) Ehrend. & Y.P. Guo subsp. *maritima*, *Calamagrostis arenaria* subsp. *arundinacea* (Husn.) Banfi, Galasso & Bartolucci, *Artemisia campestris* subsp. *variabilis* (Ten.) Greuter, *Cakile maritima* Scop. subsp. *maritima*, *Convolvulus soldanella* L., *Centaurea seridis* subsp. *sonchifolia* (L.) Greuter, *Euphorbia peplis* L., *Crithmum maritimum* L., *Cyperus capitatus* Vand., *Echinophora spinosa* L., *Elymus farctus* (Viv.) Melderis, *Eryngium maritimum* L., *Glaucium flavum* Crantz, *Jasione montana* L., *Lobularia maritima* (L.) Desv., *Lotus cytisoides* L., *Matthiola sinuata* (L.) W.T. Aiton, *Medicago marina* L., *Paronychia argentea* Lam., *Polygonum maritimum* L., *Reichardia picroides* (L.) Roth, *Reseda alba* L. subsp. *alba*, *Salsola tragus* L., *Silene vulgaris* subsp. *tenoreana* (Colla) Soldano & F.Conti, *Sporobolus virginicus* (L.) Kunth., with other native species such as *Asparagus acutifolius* L., *Asphodelus ramosus* L. subsp. *ramosus*, *Chondrilla juncea* L., *Cynodon dactylon* (L.) Pers., *Linaria vulgaris* Mill. subsp. *vulgaris*, *Retama raetam* subsp. *gussonei*, *Rhamnus alaternus* L. subsp. *alaternus*, *Scolymus hispanicus* L. subsp. *hispanicus*, *Tamarix africana* Poir., *Verbascum macrurum* Ten. and a few alien taxa such as *Acacia saligna* (Labill.) H.L. Wendl., *Amaranthus blitoides* S. Watson, *Arundo donax* L., *Carpobrotus acinaciformis* (L.) L.Bolus, *Cestrum parqui* L'Her., *Eucalyptus camaldulensis* Dehnh. subsp. *camaldulensis*, and *Ricinus communis* L.

The *Ephedra fragilis* individuals found at Capo Bruzzano live on a semi-rupicolous steep slope, where soil is almost absent and the rocky basement is mainly represented by schist. The finding of this species in an area formerly investigated, although not systematically (Caruso 2015), confirms how difficult is to observe a small isolated individual in environments different from coastal dunes. The local flora reflects the mixed ecology of this cliff and the anthropic action: *Acanthus mollis* L. subsp. *mollis*, *Allium commutatum* Guss., *A. subhirsutum* L. subsp. *subhirsutum*, *Artemisia arborescens* (Vaill.) L., *Bituminaria bituminosa* (L.) C.H. Stirt., *Cytisus infestus* (C. Presl) Guss. subsp. *infestus*, *Centaurea sicula* L., *Centranthus ruber* (L.) DC. subsp. *ruber*, *Charybdis maritima* (L.) Speta, *Convolvulus elegantissimus* Mill., *Crithmum maritimum* L., *Daucus carota* subsp. *drepanensis* (Lojac.) Heywood, *Dittrichia viscosa* (L.) Greuter subsp. *viscosa*, *Euphorbia dendroides* L., *Ferula communis* L. subsp. *communis*, *Ficus carica* L., *Galactites tomentosus* Moench, *Hyparrhenia sinaica* (Delile) G. López, *Linum usitatissimum* subsp. *angus-*

Fig. 3. Distribution of *Ephedra fragilis* plants in continental Italy stands. A = San Ferdinando N #1, B = San Ferdinando N #2, C = Capo Bruzzano.

tifolium (Huds.) Thell., *Lobularia maritima* (L.) Desv., *Lotus creticus* L., *Lygeum spartum* L., *Moricandia arvensis* (L.) DC., *Pancratium maritimum* L., *Phagnalon rupestre* subsp. *illyricum* (H. Lindb.) Ginzb., *Phlomis fruticosa* L., *Pistacia lentiscus* L., *Stachys major* (L.) Bartolucci & Peruzzi, *Rubia peregrina* L., *Scorpiurus muricatus* L., *Sixalix atropurpurea* (L.) Greuter & Burdet, *Smilax aspera* L., *Sulla coronaria* (L.) Medik., *Teucrium flavum* L. subsp. *flavum*, *Urospermum dalechampii* (L.) F.W. Schmidt.

A few threats persist for this plant in the studied area according to IUCN-CMP Unified Classification of Direct Threats (IUCN-CMP, 2013): small numbers of individuals (38), very few sub-populations (3), exiguity of suitable environment, recreative use of the area (1.3 Tourism & Recreation Areas), occurrence of alien invasive plant species such as *Acacia cyanophylla*, *Cestrum parqui*, *Eucalyptus camaldulensis*, *Pinus* sp. (8.1 Invasive Non-Native/Alien Species/Diseases), instability of the landslide slope at Capo Bruzzano (9.3.2 Soil Erosion, Sedimentation; 10.3 Avalanches/Landslides). Because of the persistent threats the species could still be considered highly at risk in the area, so deserving special measures of long-term monitoring and conservation.

Conclusions

The survey carried on along the coasts (and close inland) in selected areas of different regions of Central and Southern Italy, suggests that although the occurrence of *E. fragilis* on continental Italy cannot be categorically excluded, the only known stands of this species are actually located in Southern Calabria, two at San Ferdinando (Tyrrhenian coast), and one at Capo Bruzzano (Ionian Coast). Although numbers are at the moment increasing at San Ferdinando, the species is still locally under real extinction risk.

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Addresses of the authors:
Giuseppe Caruso[1*] & Giulia Montepaone[2],
[1]Istituto Tecnico Agrario "V. Emanuele II", via Cortese 1 – 88100 Catanzaro -Italy.
E-mail: caruso_g@libero.it
[2]Università "Mediterranea" di Reggio Calabria, località Feo di Vito – 89122 Reggio di Calabria, Italy.
*corresponding author.