

Research article

Distribution, demography and conservation perspectives of *Retama raetam* subsp. *gussonei* (Fabaceae) in Calabria (S Italy)

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Abstract: The southernmost region of peninsular Italy, Calabria, hosts two well distinct sub-populations of *Retama raetam* (Forssk.) Webb. subsp. *gussonei* (Webb) Greuter (Fabaceae), a Sicilian-Calabrian endemic shrub. The population study model applied to this work on Calabrian sub-populations of this threatened taxon, demonstrated to be a powerful tool. A preliminary survey on a sample of the studied plants enabled the fast, easy and complete collection of biometric/anagraphic data. Present number of censused plants (1,523; 82.5% by the Ionian Sea, 17.5% by the Tyrrhenian), the complex and heterogeneous composition of the population (divided in four biometric/age classes and spread on nine different sectors), its distribution within the study area, its evolution as a result of spontaneous population dynamic or future management actions, might be hopefully long term monitored through the study model here applied.

Keywords: biometry, Calabria, conservation, demography, endemism, *Retama raetam* subsp. *gussonei*

Introduction

Calabria (Fig. 1D), located at the centre of the Mediterranean basin, is the southernmost part of Italian Peninsula. It's surrounded by about 740 km of coasts, most of which are sandy and altered by human settlement.

Retama Raf. is a genus belonging to Fabaceae family, close to *Spartium* L. and *Genista* L. (Webb, 1843; Zohary, 1959). *Retama raetam* (Forssk.) Webb subsp. *gussonei* (Webb) Greuter is the European vicariant (Peruzzi & Cesca, 2003) of *R. raetam* (Forssk.) Webb subsp. *raetam*, a N-African-SW-Asiatic taxon. This subspecies is a S-Sicilian-Calabrian endemic (Caruso et al., 2010a). The Calabrian population encompasses two geographic sub-populations, the first of which located by the Ionian Sea, the second by the Tyrrhenian Sea (Fig. 1A-B-C-D).

The Ionian sub-population, located in the northern part of the Cirò Municipality (Crotone Province), occurs close to seacoast (about 50–600 m inland from

the coastline). The investigated area is encompassed SE by the final part of the Vota Ranna Stream (or Santa Venere Stream), NE by the Ionian Sea, NW by Carafuno di Cappellieri Stream and SW by the municipal road (Fig. 1A). The investigated area has altitude ranging 0–60 m a.s.l. and is crossed by the cited small streams as well as by Godano Stream, a small intermittent watercourse. Substrata are mainly fixed alluvia and dunes (Marchetti et al., 1968a-c). An inwards morphological terrace (silty clay, sands, and conglomerates) occurs, while around watercourses alluvial substrata prevail (Fig. 2A). The area is crossed by the national road S.S. 106 and by the railway following the coast line about 200–400 m inland (Fig. 1A). NE of the railway line, the landscape is dominated by exotic woody species plantations such as *Eucalyptus camaldulensis* Dehnh. subsp. *camaldulensis*, *Pinus halepensis* Mill., *Pinus pinea* L., *Acacia saligna* (Labill.) H.L. Wendl. The inland slope of dunes is mostly dominated by *R. raetam* subsp. *gussonei*. W of the S.S. 106 a vegetation mosaic occurs, encompassing

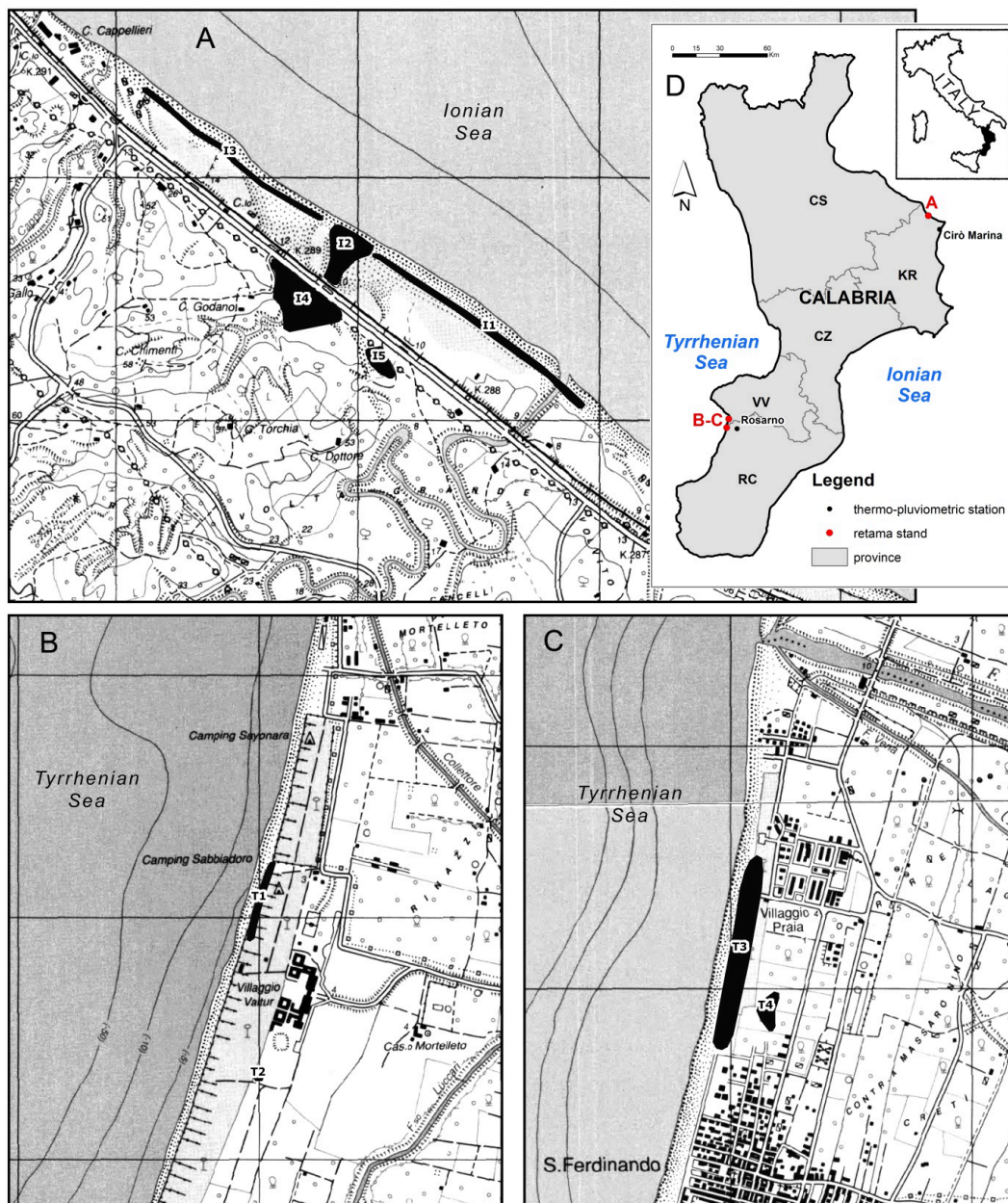


Fig. 1. Calabrian sub-populations of *R. raetam* subsp. *gussonei* (black patches) (Ionian: I1-I2-I3-I4-I5; Tyrrhenian: T1-T2-T3-T4) and thermo-pluviometric stations position (1 × 1 km grid).

both small Mediterranean steppe patches (especially close to S.S. 106), areas of Mediterranean maquis, and *R. raetam* subsp. *gussonei* vegetation. The inland landscape is dominated by cultivations (Gangale et al., 2008; Uzunov et al., 2009). Important threatening factors on Ionian stands are weeds such as *Acacia saligna* and *Carpobrotus edulis* (L.) N.E. Br. Both of them seem able to occupy wide areas of the dune system at the expenses of native flora, *Retama* included.

Tyrrhenian sub-population occurs in a coastal area (around 400 m from coast line inwards) belong-

ing to San Ferdinando (Reggio Calabria Province) and Nicotera municipalities (Vibo Valentia Province) (Caruso et al., 2010a). The area is crossed by water-courses, the most important of which is Mesima Stream. The dune system is altered and ecologically fragmented due to human activities (buildings, tourist facilities, roads, cultivations, exotic woody species plantation) and weeds such as *Cestrum parqui* L'Hér., which is probably the most hazardous. Anyway, the relict semi-natural coastal area hosts also the rare *Ephedra fragilis* Desf. (Caruso et al., 2010b; Caruso

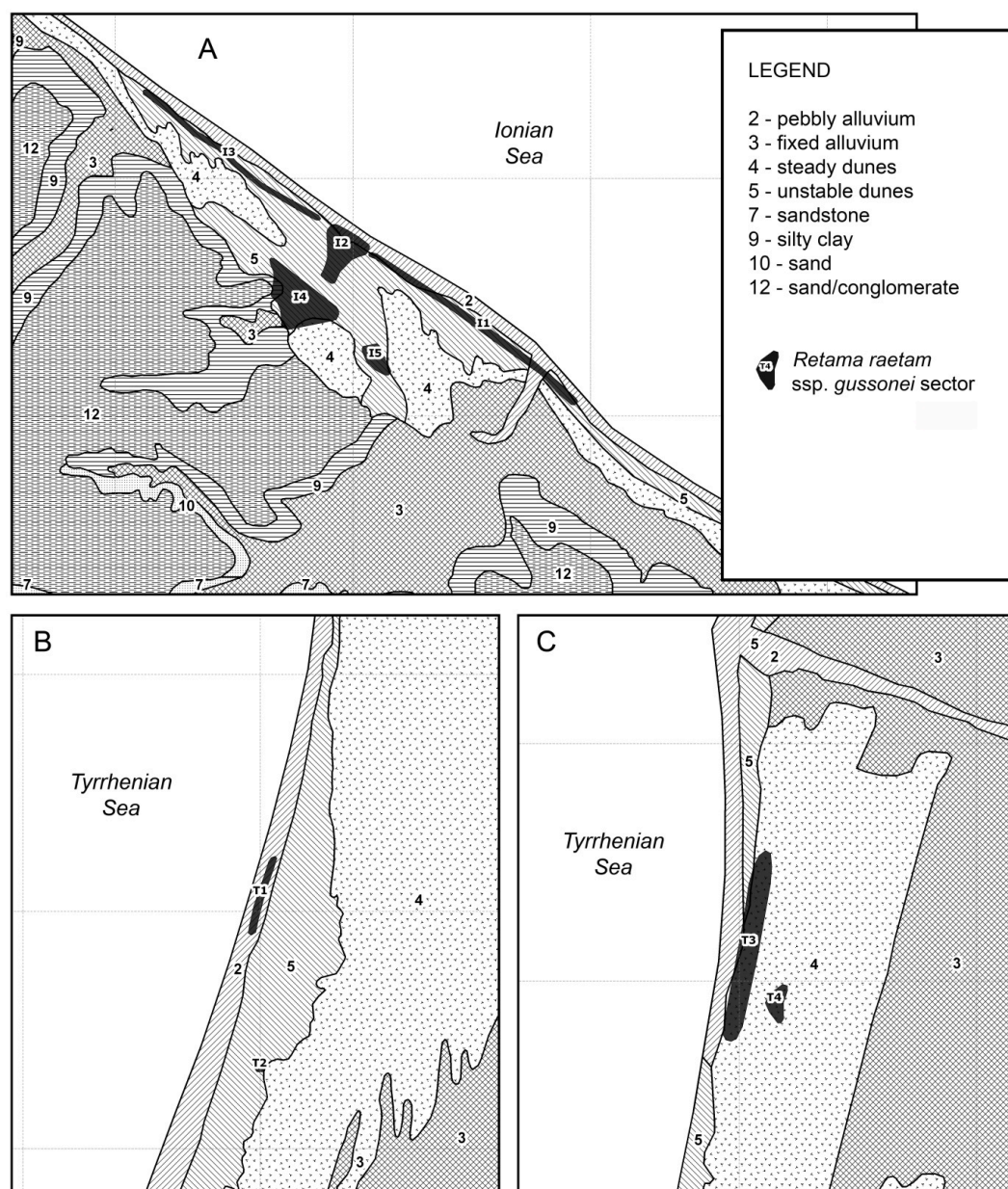


Fig. 2. Geological map of the coastal areas interested by the occurrence of *R. raetam* subsp. *gussonei* in Calabria (Marchetti et al., 1968a, b, c modified) on 1 × 1 km grid.

et al., 2012; Caruso & Montepaone, 2020). From the geological point of view alluvia and dunes prevail (Marchetti et al., 1968b; Fig. 2B-C), although the whole district is currently undergoing an important erosion process (Chiaravalli et al., 1990; D'Alessandro et al., 1992).

R. raetam subsp. *gussonei*, according to IUCN criteria, was formerly considered Critically Endangered (CR) at regional and national level (Conti et al., 1997), but has been later redefined as Endangered EN B1ab(iii)+2ab(iii) (Caruso et al., 2010a).

Macrobioclimate, according to Rivas-Martínez & Rivas-Sáenz (1996–2009), in both localities is Mediterranean pluviseasonal-oceanic, upper thermomediterranean, upper dry. The low subhumid umbrotypage registered at the Rosarno thermo-pluviometric station depends on its altitude and inland location (Fig. 3), rather far from the Tyrrhenian *Retama* stands.

Calabrian stands of *R. raetam* subsp. *gussonei* are threatened by anthropic activities (agriculture, woody plant cultivation, grazing, human settlement, alien in-

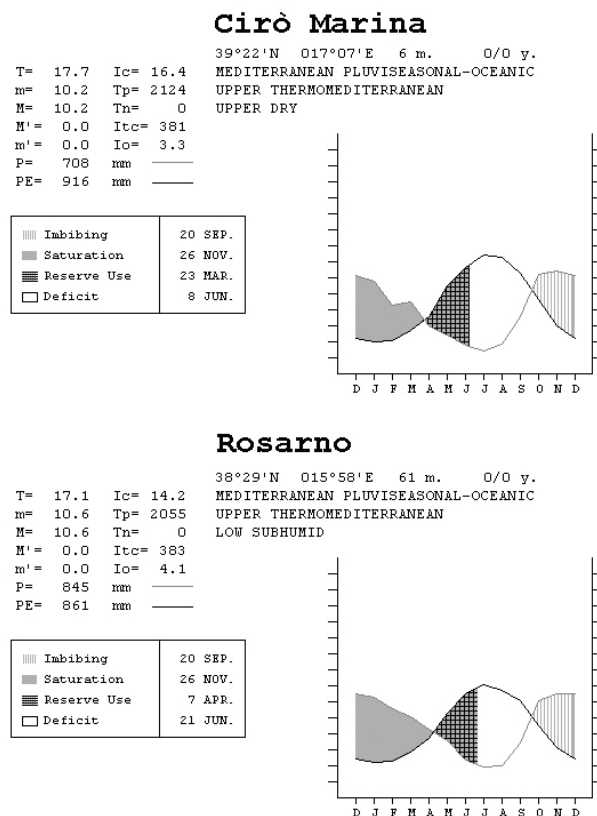


Fig. 3. Bioclimate of Cirò Marina and Rosarno thermo-pluviometric stations according to Rivas-Martínez & Rivas-Sáenz (1996–2009).

vasive species, fire) (Caruso et al., 2010a), as well as illegal sand uptake and coastal erosion (Chiaravalli et al., 1990; D'Alessandro et al., 1992). Some exotic species found in the area do not apparently reproduce [e.g. *Eucalyptus camaldulensis* subsp. *camaldulensis*, *Opuntia subulata* (Mühlenpfordt) Engelm. in Gard] while other are rapidly expanding [e.g. *Cestrum parqui* L'Hér, *Carpobrotus edulis* (L.) N.E. Br., *Acacia saligna*, *Opuntia maxima* Miller, *Pinus pinea*, *Pinus halepensis*] (Caruso et al., 2007; Caruso et al., 2010a).

Aim of this work is to develop an easy-to-apply, low time-consuming, low-invasive scientific model to study shrub-like species population demography. Moreover, considering the present level of risk of extinction in the area of this rare endemic taxon, this work aims to provide detailed quantitative and qualitative data on Calabrian population of *R. raetam* subsp. *gussonei*, its demographic structure and geographical distribution. This may contribute to management policy needed to ensure population long term monitoring and conservation.

Materials and methods

The field work has been carried out mainly during 2007 and 2008 spring-summers, but additional information has been collected until the 2022 summer. The identification of the collected material has been done according to Flora d'Italia (Pignatti, 1982; Pignatti, 2017–2020) and Flora Europaea (Heywood, 1967).

Study area

Considering the physical (e.g. roads, railway, villages, camp areas, cultivated fields, disturbed areas, etc.) and biological barriers (e.g. exotic woody species forest) existing, inside the areas where *R. raetam* subsp. *gussonei* occurs, ecologically uniform sectors have been delimited (5 by the Ionian Sea, 4 by the Tyrrhenian) as shown in Fig. 1.

Biometric-anagraphic development model

Before starting the census operation, a preliminary study has been necessary in order to define a simple, low time-consuming, low-invasive sampling technique suitable to know, with statistically acceptable approximation, the age of each single plant belonging to the studied population. *R. raetam* subsp. *gussonei* plants have, if observed from above, a circular shape. This depends on the uniform distribution in all directions of the branches from central stem axis (Fig. 4). A simple way to estimate the age (or age range) of this shrub, is to measure (or estimate) the diameter of the projection of the plant canopy on the ground. Except the infertile juvenile plants (class 0 = 0–0.5 m), the reproductive population of the surveyed species has been therefore arbitrarily divided into 4 biometric classes, based on the diameter of the projection of the canopy on the ground (class 1 = canopy diameter 0.5–1 m; class 2 = 1–2 m; class 3 = 2–3 m; class 4 = 3–6 m) (Fig. 4; Table 1). The next step has been to verify whether these biometric classes were in fact correspondent to different age groups. For this purpose the architectural/anagraphic structure of plants has been studied in detail. A first sample, made of 30 plants belonging to all morphological classes, have central stem axis and branches sampled by a Pressler gimlet. For each sample of wood annual rings have been counted, and so has been determined the age of each

Table 1. Biometric classes and age (in years) range measured on Calabrian population of *R. raetam* subsp. *gussonei* and correlation coefficient (*r*) among some of the measured parameters.

biometric class	acronym	cd	obd	obaa	ob/caa	pa
	biometric parameter	canopy diameter	outer branches diameter	outer branches average age (age range)	outer branches/central axis age difference	plant age
	measure unit	m	cm	year	year	year
0	seedling/not reproductive juvenile	0–0.5	—	—	—	0–4
1	young fertile	0.5–1	1.4	4.4 (3–6)	2–3	5–9
2	young fully fertile	1–2	1.9	6.2 (5–8)	3–4	8–12
3	adult	2–3	2.4	7.0 (6–9)	4–5	10–14
4	senescent	3–6	3.7	10.8 (8–15)	5–6	13–21
	<i>r</i>		cd-obd 0.998902131	cd-obaa 0.991141116		cd-pa 0.994364681

part of studied plants (Fig. 4). From these data it was possible to know, for each sampled plant, the individual age (= rings of central axis) and the age of the outer branch (= rings of branch). Consequently, has been possible to know the relationship among outer branch age, individual age and plant canopy diameter for each studied plant and all biometric classes (Fig. 4; Table 1). The biometric-anagraphic survey, as shown ahead (Table 1), demonstrated the existence of a close correlation among the average values of plant age, the outer branch age and the canopy diameter. This allowed, following the opposite path, on a second sample made of 120 plants, to know the age of a single plant just through the age of the outer branch easily sampled by Pressler gimlet. Moreover, once calculated the age range of each biometric class, it has been possible to trace the age range of each plant just measuring the canopy diameter. This demonstrates, for the surveyed taxon, the diameter of the canopy projection on the ground to be a reliable and easy-to-assess parameter for an effective biometric-anagraphic classification of plants.

Population census and analysis

The reproductive Calabrian population of *R. raetam* subsp. *gussonei*, represented by the 4 biometric classes above described, has been censused.

Seedlings and not reproductive juveniles (canopy diameter < 50 cm) have been excluded from the present analysis because difficult to count in the field and because of the already known high death rate (Peruzzi & Cesca, 2003). The occurrence of these individuals has just been recorded, but not quantified, inside all sectors. A quanti-qualitative analysis on the whole Calabrian population of the surveyed species has been carried on in the different sectors considering the biometric classes.

Results and discussion

Biometric classes and plant development model

Biometric-anagraphic sampled measures provided data summarised in Table 1.

The study of populations of rare species and characterising of their development models are used in different study (Pogorzelec et al., 2023; Sakhraoui et al., 2024). Several plants belonging to the biometric class 0 (canopy diameter 0–0.5 m) have been found in each sector of the study area. This class, excluded by the current analysis for the reasons above explained, is composed by plants younger than 4 years (seedlings/not reproductive juveniles), usually infertile. Class 4 has not been split in different classes because very few plants with a canopy diameter wider

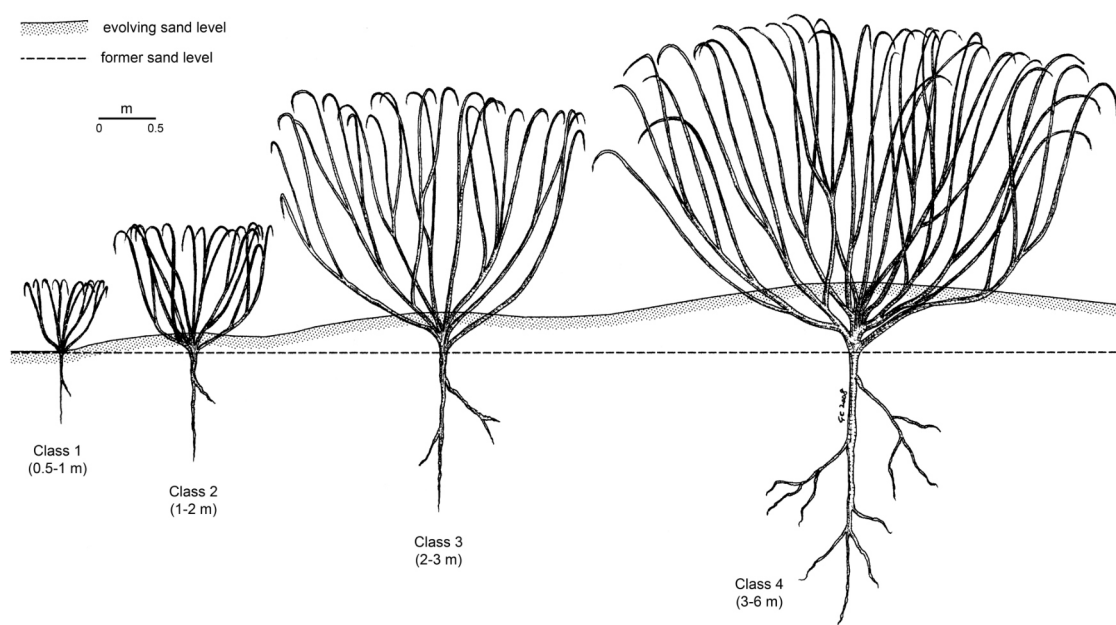


Fig. 4. Phases of morphological development in a *R. raetam* subsp. *gussonei* plant, corresponding to biometric classes adopted in this study and following the dune system evolution.

than 4 m have been found. Besides, these wider plants grow mainly isolated inside clearings. It has been believed that uncommon size reached by these plants was mainly due to the absence of competition, and consequently was poorly significant. Biometric-anagraphic study showed that branches belonging to a single plant do not have the same age. Stem axis is the oldest part of the plant, while the outer branches are the youngest and inner branches are in between. Despite some overlapping values of plant age (e.g. classes 2, 3 and 4 in Table 1), probably due to micro-ecological factors locally affecting morphological development of plants, Table 1 shows high values of correlation (r) among canopy projection diameter and outer branch diameter (0.999), as well as canopy projection diameter and outer branches average age (0.991) and even canopy projection diameter and plant age (0.994). These make the canopy diameter, at least for the purpose of this work, a statistically reliable measure of individual age (or age range) for this taxon in the investigated area.

Population census and analysis

The features of Calabrian population *R. raetam* subsp. *gussonei* are summarised in Table 2, a double entry table where columns correspond to biometric classes

and rows represent sectors (Ionian sectors: I1-I2-I3-I4-I5; Tyrrhenian sectors: T1-T2-T3-T4). Each biometric class (with the only exception of class 0) is represented by two sub-columns. The sub-column on the left side of the table contains the number of plants belonging to that class occurring in that specific sector; the sub-column on the right contains the percentage value of that class on the total amount of plants occurring in that specific sector. Similarly, each sector is represented by two rows. The upper row corresponds to the above described left column value, so contains the number of plants for that class in that sector. The lower row contains the percentage value of that sector on the total amount of plants belonging to a specific class. For example, inside the class 1, in the first column there is 6, in the second 13.6, in the lower row 1.2. This means that inside the sector I1 6 plants belonging to class 1 occur; this class represents 13.6% of total individuals occurring in the sector I1; this means also that in the sector I1 1.2% of plants belonging to the whole class 1 occur. Grey column on the right summarise data per each sector, while the grey row at bottom summarise data per each class. The two columns at the extreme right host aggregate data (and %) of Ionian and Tyrrhenian sub-populations.

The overall Calabrian population of *R. raetam* subsp. *gussonei* counts 1,523 fertile plants. Ionian subpopulation is clearly prevalent with 82.5% of the

Table 2. Calabrian population of *R. raetam* subsp. *gussonei* censused within 9 sectors, 5 of which correspond to the Ionian sub-population (I), and 4 to the Tyrrhenian (T) one.

				biometric classes								total sectors		sub-populations		
				class 0	class 1		class 2		class 3		class 4					
				pres	nr	%	nr	%	nr	%	nr	%	nr	%	nr	%
sectors	Ionian	sector I1	nr	+	6	13.6	12	27.3	25	56.8	1	2.3	44	2.9	1,256	82.5
			%		1.2		2.8		4.7		1.4					
		sector I2	nr	+	93	28.9	122	37.9	67	20.8	40	12.4	322	21.1		
			%		18.7		28.8		12.6		58					
		sector I3	nr	+	45	9.8	106	23.2	281	61.5	25	5.5	457	30		
			%		9		25.1		52.7		36.2					
		sector I4	nr	+	37	15.5	57	23.8	145	60.7			239	15.7		
			%		7.4		13.5		27.2							
		sector I5	nr	+	124	63.9	70	36.1					194	12.7		
			%		24.9		16.5									
	Tyrrhenian	sector T1	nr	+	5	17.9	18	64.3	4	14.3	1	3.5	28	1.8	267	17.5
			%		1		4.3		0.8		1.4					
		sector T2	nr	+			1	100					1	0.1		
			%				0.2									
		sector T3	nr	+	188	80.3	34	14.5	10	4.3	2	0.9	234	15.4		
			%		37.8		8.1		1.9		2.9					
		sector T4	nr	+			3	75	1	25			4	0.3		
			%				0.7		0.2							
total classes			nr	+	498		423		533		69		1,523			
			%		32.7		27.8		35		4.5		100			

whole population (1,256 plants), while Tyrrhenian subpopulation counts just 267 plants (17.5%) (Table 2).

Considering the distribution of plants among biometric classes it can be noticed that class 1 (498 plants; 32.7% of total), class 2 (423; 27.8%) and class 3 (533; 35%) are rather balanced (around 1/3 each), while class 4 (69; 4.5%) is the less represented. The oldest component of the population (class 4) seems to be quantitatively less important, while the youngest components are dominant. A situation like this is expected in a healthy population with a good reproductive perspective.

Analysing the population by sectors it is evident that the most plant-rich sector is I3 (457 plants; 30% of the whole population); it follows sector I2 (322; 21.1%), sector I4 (239; 15.7%), sector T3 (234;

15.4%), sector I5 (194; 12.7%); quite far it follows sector I1 (44; 2.9%), T1 (28; 1.8%), T4 (4; 0.3%) and T2 (1; 0.1%).

The biometric classes are heterogeneously distributed among sectors. Class 1 prevails in sector I5 (124 plants; 63.9% of the sector) and in sector T3 (188; 80.3%). Class 2, conversely, prevails in sector I2 (122 plants; 37.9% of the sector) and T1 (18 plants; 64.3% of the sector). Class 3 prevails in sectors I1, I3 and I4 respectively with 25 plants (56.8% of the sector), 281 (61.5%) and 145 plants (60.7%). Class 4 is best represented in sector I2 (40 plants; 58%) and sector I3 (25 plants; 36.2%). The richness of young plants (class 1) into sector I5 is mainly due to a wildfire occurred during 2003 and responsible of the destruction of all adult plants of this sector (Table 2; Fig. 5). Because recently discovered (Caruso et al., 2010a) no histori-

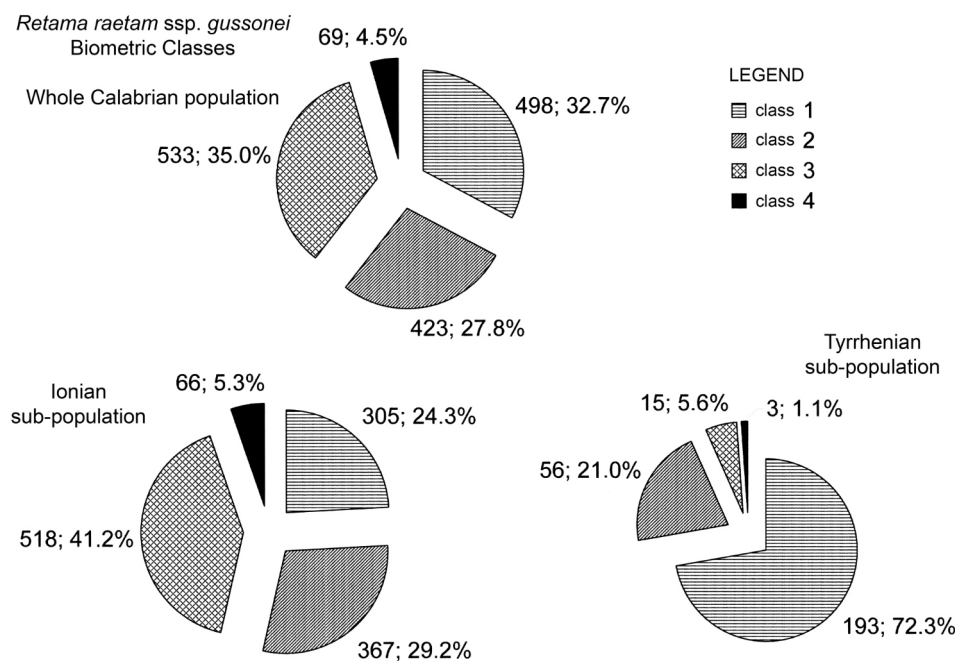


Fig. 5. Absolute and percentage importance of biometric classes of *R. raetam* subsp. *gussonei* on the whole Calabrian population, on the Ionian sub-population and on the Tyrrhenian sub-population.

cal distribution data are available about Tyrrhenian Calabrian stands of *R. raetam* subsp. *gussonei*. Randomly interviewed local elderly report a wider distribution of *R. raetam* subsp. *gussonei* by the Tyrrhenian coast of Calabria in the past. Human activities and coastal erosion reduced this area severely fragmenting it. Some weedy species (e.g. *Acacia saligna*) seems now to have a stable population, at least in some tracts of the coast where frequent are ruinous attempts of *Citrus* sp. div. cultivation. The recent formation of small patches of *R. raetam* subsp. *gussonei* in these abandoned orchards probably could explain the frequency of young plants (class 1) and, in the long term, could lead this rare taxon to recover part of the presumed former area of occurrence.

Geomorphological role

R. raetam subsp. *gussonei* plays an important geomorphological role contributing to create and stabilise the dune system. Sand moved by wind is stopped by plant branches, so tending to accumulate at the plant base mixed with litter. This determines the progressive uplift of the dune top and the partial burial of plant's branches. Considering that number and age of

branches increases with plant age and that in juveniles first branch is above the ground level, while in the adults is mostly covered by sand, the average dune uplift during the plant life (up to 20 years) is 50 (20–80) cm (Fig. 4).

Long term monitoring and conservation

As part of the European Natura 2000 network the Site of Community Importance (SCI) IT9320100 named “Dune di Marinella” has been created on the Ionian coast of Calabria (Regione Calabria, 2003) in order to protect an important nesting place of *Caretta caretta* L. (Cheloniidae) and rare and endemic plant species such as *Centaurea deusta* Ten. (Asteraceae), *Hypocoum imberbe* S. et S. (Papaveraceae), *Ephedra distachya* L. subsp. *distachya* (Ephedraceae), *Artemisia variabilis* Ten. (Asteraceae) etc. and habitats, also priority (*), listed in EEC Directive 92/43, such as 6220* (Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*), 2240 (*Brachypodietalia* dune grasslands with annuals), 9320 (*Olea* and *Ceratonia* forests), 2210 (*Crucianellion maritimae* fixed beach dunes), 5330 (Thermo-Mediterranean and pre-desert scrub), 2120 (Shifting dunes along the

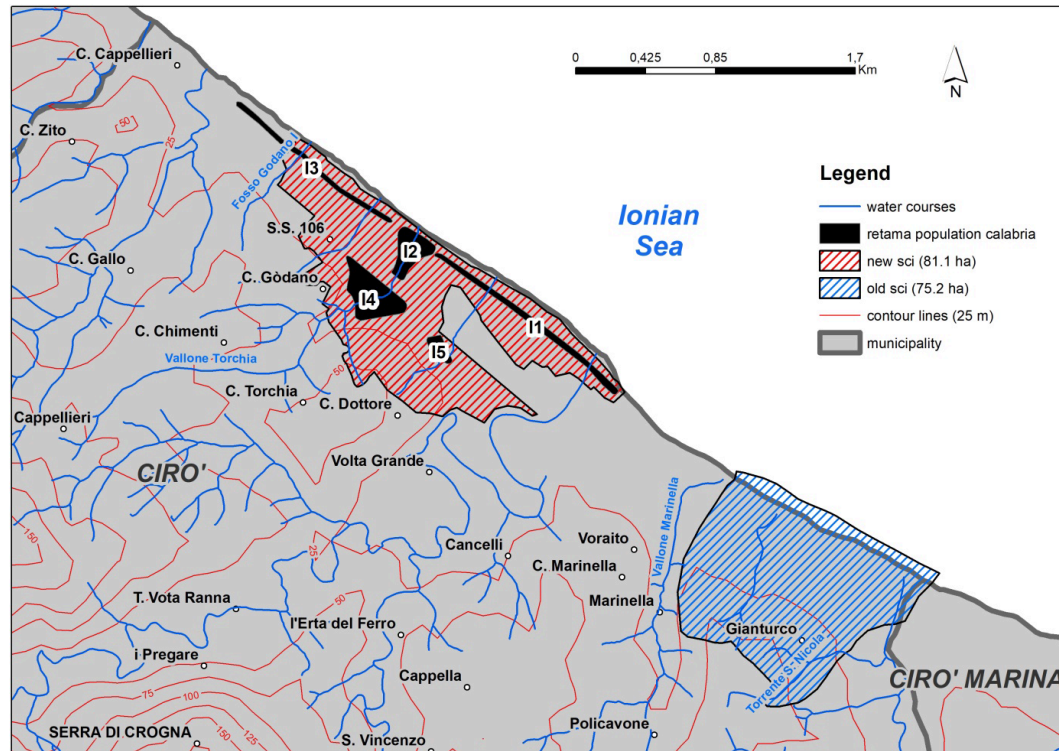


Fig. 6. Old (blue lines) and new (red lines) official perimeters of the “Dune di Marinella” SCI, the second one re-drawn in order to really include the Ionian *R. raetam* subsp. *gussonei* stands of Calabria (black).

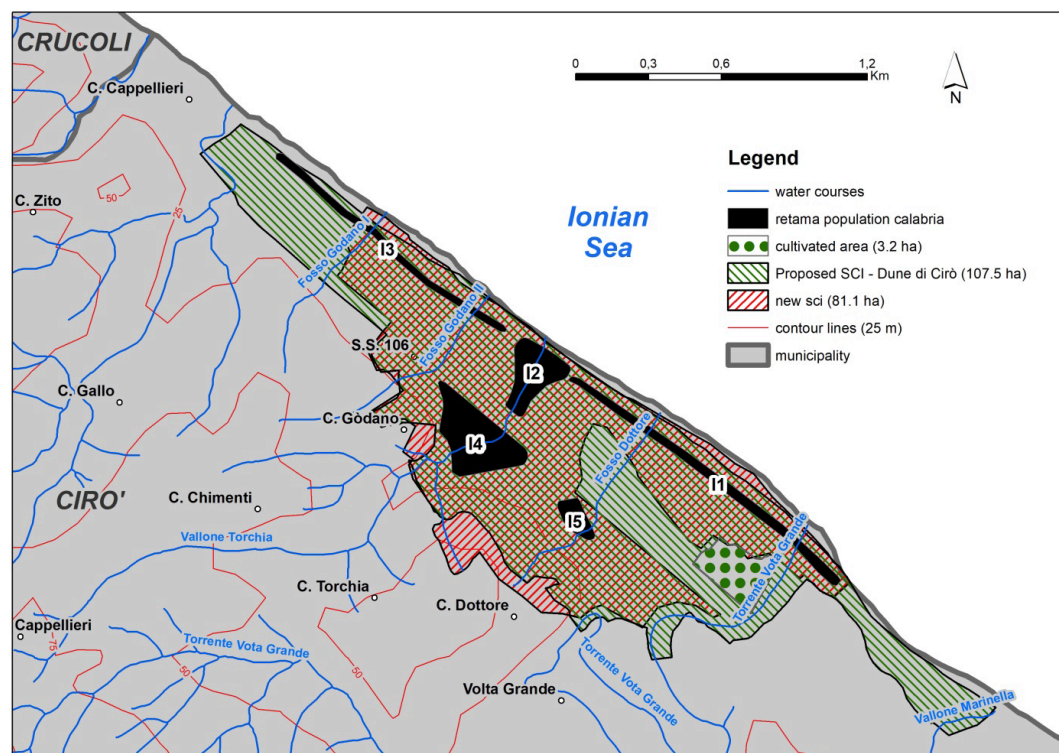


Fig. 7. The official current perimeter of “Dune di Marinella” SCI (red lines), overlapping the here proposed new perimeter (green lines + green dots) re-drawn according to the criticalities emerged during the present survey.

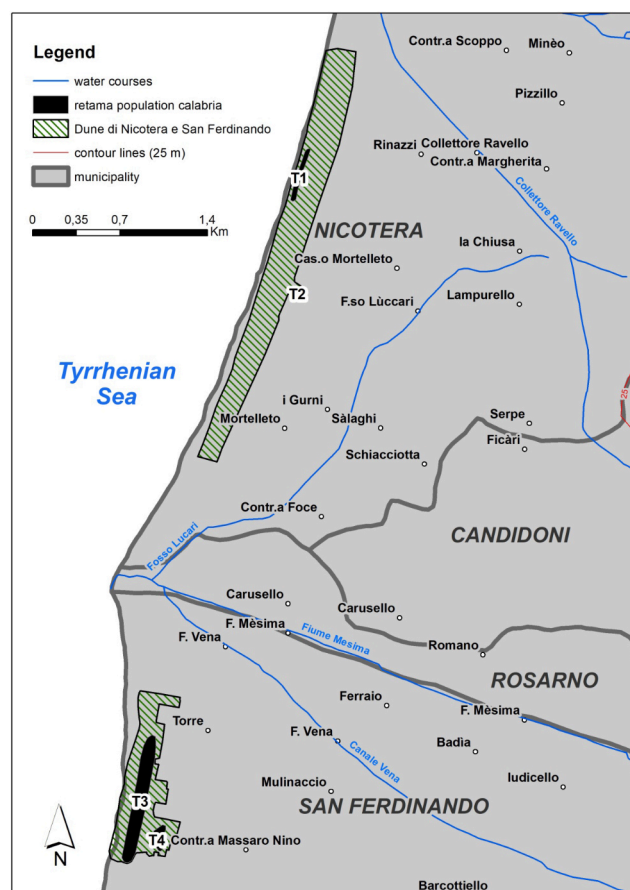


Fig. 8. Areas by the Calabrian Tyrrhenian coast where *R. raetam* subsp. *gussonei* occurs, and proposed new protected area, divided in two sectors (the southernmost of which including also an *Ephedra fragilis* stand), possibly named “Dune di San Ferdinando e Nicotera Marina”.

shoreline with *Ammophila arenaria*, white dunes), 2230 (*Malcolmietalia* dune grasslands) (European Commission Environment, 2012; Biondi et al., 2012). Nonetheless, the former perimeter of the Dune di Marinella SCI did not really encompassed the Ionian *R. raetam* subsp. *gussonei* stands. That’s why a new perimeter has been drawn including the area where Ionian *R. raetam* subsp. *gussonei* stands occur (Fig. 6) while the old perimeter of the SCI has been deleted by the Rete Natura 2000 network. Nonetheless, a few criticalities emerged along with the new official perimeter. Firstly, the new SCI perimeter shows a deep inlet on the SW side, probably in order to avoid the inclusion of a cultivated area (Figs 6–7). This area is mainly characterised by low productive sandy soils (Fig. 2), constantly at risk of abandonment, mostly intended for herbaceous annual crops while the Cirò area is commonly renowned for high

quality viticulture. On the other hand, the area could represent a future opportunity for *Retama* plants to colonise new habitats, therefore deserves to be included in the SCI perimeter, so providing also a more compact shape to the protected area. Second, the new official perimeter excluded some plants (Fig. 6) belonging to the I3 sector, in the NE of the Ionian distribution area. Third, in the SE corner of the new official perimeter some olive tree cultivations have been, maybe erroneously, included. Fourth, the name of this SCI can no longer be “Dune di Marinella”, because “Marinella” is a locality currently far from the SCI new official perimeter. Considering these observations, is here proposed, for the SCI area, the new name “Dune di Cirò” (meaning “Dunes of Cirò” in Italian), and a new perimeter (Fig. 7), virtually resolving all the recorded issues properly.

The lack of protection measures, the altered environment, as well as the Tyrrhenian *R. raetam* subsp. *gussonei* population size and structure, expose it to a high risk of extinction. Being the area also interested by the occurrence of one of the only two known stands of *Ephedra fragilis* Desf. of peninsular Italy (Caruso et al., 2009; Caruso et al., 2010b; Caruso et al., 2012; Caruso & Montepaone, 2020), it should be justified the establishment of a new protected area in this territory. The proposed protected area (as a floristic protected area, regional park or, better, as a SCI), possibly named “Dune di Nicotera Marina e S. Ferdinando”, would adopt measures against further anthropic pressure.

Long term conservation of this precious taxon largely depends on the environmental quality and on the possibility to maintain and even increase the present area of occurrence. The dangerous co-occurrence of invasive species such as *Carpobrotus edulis* (Ionian stands), *Cestrum parqui* (Tyrrhenian stands) or *Acacia saligna* (Ionian and Tyrrhenian stands) strongly affects the surveyed species actively competing for space and resources. In order to preserve the existing stands of *Retama raetam* subsp. *gussonei* the complete eradication of these alien taxa seems to be the only solution. The other woody exotic species widely planted in the surveyed area, although not invasive, occupy a large surface potentially useful to increase the present *R. raetam* subsp. *gussonei* area of occurrence. A progressive programme of eradication should be in this case a good solution.

Considering the IUCN category to which this taxon belongs and the persistence of threatening factors

on studied sub-populations, a long term monitoring programme must be urgently planned. Considering biology and ecology of this taxon, applying the methodology developed as part of this work, the frequency of monitoring should be 3–10 years. This would allow comparable data to be easily collected. As the eradication of weeds proceeds a 2–3-year monitoring protocol should be scheduled in order to lead dynamic management.

Conclusions

The population study model applied to this survey on Calabrian sub-populations of *R. raetam* subsp. *gussonei* demonstrated to be a very powerful tool. A preliminary survey on a sample of investigated plants made it possible a fast, easy and complete collection of biometric/anagraphic data on the whole population.

The present number of plants, the complex and heterogeneous composition of the population, its distribution within the study area, its evolution as a result of spontaneous population dynamic or future management actions, as well as the possible establishment of specific protected areas needed for the protection of this rare and endemic taxon in Calabria, might be hopefully long term monitored through the study model here applied.

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