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Ecology and conservation status of *Muscari gussonei* (Parl.) Nyman in Sicily: a narrow endemic species threatened by habitat reduction

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Abstract
Muscari gussonei (Parl.) Nyman (*Hyacinthaceae*) is a rare endemic psammophyte occurring in southern Sicily (Italy). It is listed as Endangered species (EN) in the Red Book of Italian plants, included in the Annex I of Berne Convention (1979), and Annex II of the Habitat Directive 92/43/EEC as a priority species. This species characterizes the psammophilous plant communities ascribed to the *Vulpio-Leopoldietum gussonei*, together with many therophytes of the *Cutandietalia maritimae* order. Aims of this work were to examine the structure and floristic composition of the *M. gussonei* community, assess its conservation status and propose conservation measures. This study is part of a LIFE project (LIFE11 NAT/IT/000232 - Action D.1). Distribution and population structure were investigated through many field surveys carried out between 2013 and 2015. In order to define the ecological requirements of *M. gussonei*, 10 permanent plots were designed, while for characterizing the habitat of *M. gussonei* 41 phytosociological reléves were randomly carried out. Classification of relevés by using cluster analysis revealed three plant communities with *L. gussonei*, each with specific key species and linked to different environments. Three vegetation types (white dunes, grey dunes, inland or fossil dunes) were confirmed by canonical component analysis (10 plots) and they are correlated to a gradient of ecological features ranging from coastal to inland areas. After a census of *M. gussonei* populations joined to the their mapping, the conservation status, according to IUCN guidelines, was assessed confirming the EN category. Finally, this study provides some relevant issues for the implementation of conservation measures.

Key words: conservation status monitoring, Leopoldia LIFE project, Mediterranean coastal conservation, plant distribution, population structure, psammophilous vegetation.

Introduction

Coastal dunal environments are one of the most threatened habitats of the Mediterranean area, chiefly as a result of anthropogenic destruction, habitat fragmentation and alteration (Médail & Verlaque, 1997; Acosta *et al*., 2007, 2009; De Luca *et al*., 2011; Fenu *et al*., 2012, 2013; Sciandrello *et al*., 2015; Pinna *et al*., 2015). Theses habitats are characterized by a very specialized flora, sometimes with endemic elements. One of these is *Muscari gussonei* (Parl.) Nyman (=*Leopoldia gussonei* Parl.), a small *Hyacinthaceae* species growing on sandy substrates more or less close to the coast. This species is a narrow endemic of southern Sicily (Garbari & Di Martino, 1972; Giardina *et al*., 2007; Brullo *et al*., 2011) and characterizes the psammophilous plant community named *Vulpio-Leopoldietum gussonei*, together with many other annual plants of the *Cutandietalia maritimae* order (Brullo & Marcenò, 1974; Minissale & Sciandrello, 2015). *Muscari gussonei* is an endangered species, mentioned by the 1979 Berne Convention (Annex I), included in the Annex II of the Habitat Directive 92/43/EEC as a priority conservation species (Fenu *et al*., 2017a), and listed in the Red Book of Italian plants (Conti *et al*., 1997; Rossi *et al*., 2016). Currently, *Muscari gussonei* is severely threatened by human activities, which are one of main causes of its distribution range reduction up to few and scattered populations (Vandepitte *et al*., 2012). Gussone (1827) and Lojacono-Pojero (1908-1909) recorded *Muscari gussonei* from Terranova (nowadays Gela) up to Capo Passero (SE Sicily). Afterward, Albo (1919) confirmed its occurrence in some localities of south-eastern Sicily (*e.g.* Sampieri, Marzamemi, Portopalo, etc.). Garbari & Di Martino (1972) found it at the so-called "Macconi di Gela" (Mignechi). Finally, Brullo & Marcenò (1974), while examining the survived populations of *Muscari gussonei*, were able to found the species just in few stands along the coast of Ragusa (Cammarana, Passo Marinaro, Branco Piccolo, Randello, Refriscolaro and Mignechi), while some of the sites reported by Albo (1919) disappeared likely as a consequence of anthropogenic changes (Marina della Marza, S. Maria del Focallo, Capo Isola delle Correnti, Macchitella di Gela).

The present study is part of the LIFE-Leopoldia project (LIFE11 NAT/IT/000232) (action D.1 – Monitoring of species of greater importance for conservation). In particular, one of the project aims is the restoration of degraded coastal dunes, as well as the reinforcement of the *Muscari gussonei* populations.

The aim of our research is the assessment and monitoring of the scattered surviving populations and identification of its ecological requirements both in natural

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conditions and degraded habitats.

Material and methods

Study area

The surveyed area (Fig. 1) includes the coastal belt of the southern part of Sicily, from Gela to Capo Passero, an area featured by dunes and wetlands. It is mainly characterized by Pleistocene substrates, such as calcarenites and sand deposits that often extend inland (Lentini *et al*., 1984).

This area is also very important from the phyto-geographical viewpoint. Indeed, several endemic or rare species are found, such as *Helianthemum sicanorum*, *Reaumuria vermiculata*, *Hormuzakia aggregata*, *Rhus tripartita*, *Nonea vesicaria*, *Helianthemum lippii*, *Lobularia lybica*, *Retama raetam* subsp. *gussonei*, *Serapias orientalis* subsp. *siciliensis*, *Tuberaria villosissima* var. *sicula* and *Muscari gussonei* (Brullo *et al*., 2007; Brullo & Sciandrello, 2006; Brullo *et al*., 2011; Brullo *et al*., 2013). According to the phytogeographic classification of Sicily (Brullo *et al*., 2011), this area belongs to the Camarino-Pachinense district included in the southern Sicilian subsector together with the Hyblaean district. According to the bioclimatic classification proposed by Rivas-Martínez (1993, 2004), the study area is referred to the Mediterranean pluviseasonal oceanic bioclimate, with thermotypes ranging from the lower thermomediterranean to upper thermomediterranean and ombrotypes from the lower semiarid to upper semiarid (Brullo *et al*.,1996; Bazan *et al*., 2015).

The study area includes five Sites of Community Interest (SCIs) of European Union Network "Natura 2000", *i.e.* ITA050001 "Biviere e Macconi di Gela", ITA050011 "Torre Manfria", ITA080003 "Vallata del F. Ippari (Pineta di Vittoria)", ITA080004 "Punta Braccetto, Contrada Cammarana", ITA080006 "Cava Randello, Passo Marinaro" and one Special Protection Area (SPA) ITA050012 "Torre Manfria, Biviere e Piana di Gela".

Sampling and statistical analysis

Literature focusing on the *M. gussonei* distribution range was reviewed. In addition, further dried specimens from the herbaria of Catania (CAT) and Palermo (PAL) were examined. Basing on these data, all the known sites with *M. gussonei* were visited over the period 2013-2015, and more potentially suitable sites for this species were searched. For the risk assessment, the IUCN protocol (2001) was followed according to the most recent guidelines. In particular for the extinction risk, the criterion B was applied by estimating trends in the Area of Occupancy (AOO) using a 2×2 km grid (IUCN, 2017a).

The field work, for examining structure, floristic composition and catenal contact of the surveyed plant communities, was carried out from 2013-2015, during

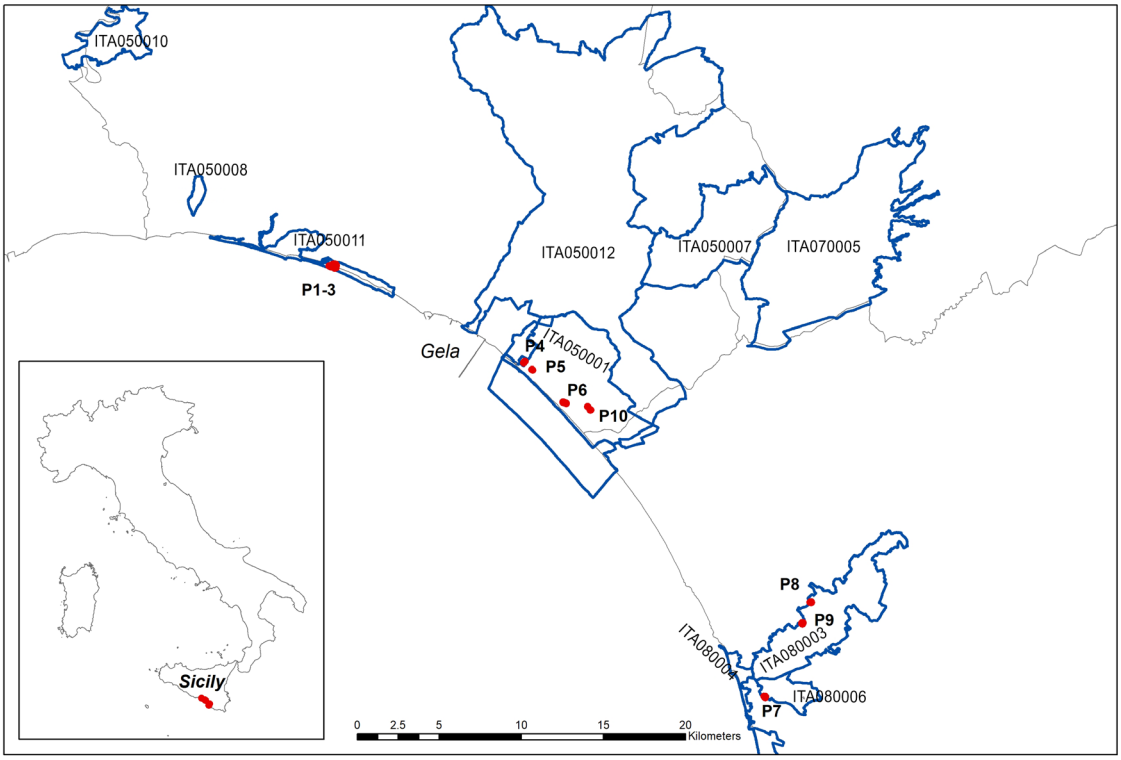

Fig. 1 - Study area and *Muscari gussonei* distribution (red dots) within Natura 2000 sites. Plots 1-3 Poggio Arena (ITA050011); Plot 4 Santa Lucia, Plot 5 Cava Cammarata, Plot 6 C.da Mignechi, Plot 10 Biviere di Gela (ITA050001); Plot 7 Passo Marinaro (ITA080006); Plot 8 C.da Gerbe, Plot 9 C.da Brancato (ITA080003).

which 41 randomly chosen reléves were performed (25-100 m^2), including woody vegetation, if any. Moreover, 10 permanent plots (2 x 2 m), featured by the therophytic plant community *Vulpio-Leopoldietum gussonei*, were identified, geo-referred and phytosociologically characterized (Braun-Blanquet, 1964; Biondi, 2011). Ten soil samples (about 2 kg each) from each plot (between 0 and 15 cm depth) so as to represent a single sedimentation event, were dried at 110 °C for 24 hours, before being analyzed. The grain size analyses were performed by dry sieving for 10 min, using a set of 32 sieves with mesh sizes ranging from 4 to 0.06 mm (Wentworth, 1922).

Numerical analysis (Cluster Analysis - UPGMA method, Euclidean coefficient) was performed using the program package SYN-TAX 2000 (Podani, 2001). Environmental gradients influencing plant communities were examined with canonical component analysis (CCA), using PC-ORD (v4.34) software. Original Braun-Blanquet sampling scale has been transformed into the ordinal scale according to Van der Maarel (1979). Species nomenclature follows Giardina *et al*. (2007) and Raimondo & Spadaro (2009), while phytosociological nomenclature is based on Biondi *et al*. (2014). For the correlation between vegetation types and habitats we referred to the Italian Interpretation Manual for the Habitats of Directive 92/43/EEC (Biondi *et al*., 2009).

Two indices were calculated for estimating the plant community diversity: (1) species richness of each vegetation cluster (SR), and (2) the Shannon-Wiener Diversity Index (H). The latter one takes into account the degree of equitability (J) of the species distribution (Morris *et al*., 2014). Spearman rank correlation coefficients (r) were used to evaluate the importance of environmental factors in the distribution of the plant diversity (De Luca *et al*., 2011; Hettenbergerová *et al*., 2013). A p-value of 0.05 was taken as indicating a statistically significant difference.

Results

M. gussonei *plant community*

The floristic diversity of the randomly chosen 41 relevés account for 63 species of vascular plants (Tab. 1). Most species belong to Mediterranean chorological elements (60%), with the dominance of therophytes (46%), followed by hemicryptophytes (21%), chamaephytes (13%) and geophytes (11%). As one may expect, a lower floristic diversity characterizes the permanent plots; in fact, a total of 48 vascular species (x 10 permanent plots) were recorded. Whereas, structure and floristic composition of the permanent plots is more or less stable during the three years of monitoring (Tab. 2).

In its optimal habitat, *M. gussonei* is associated with several annual psammophytes occurring on soils with high percentage of sand (83%) with a pH 7.63 (mean values) and low presence of organic matter (Tab. 3).

The results of the cluster analysis (41 random relevés) show two main vegetation groups, each supported by specific indicator species, because structural-dominant species of each plant community (Fig. 2). The first group (A) gathers the woody coastal plant communities dominated by *Retama raetam* subsp. *gussonei* and *Ephedra fragilis*, belonging to the *Asparago horridi-Retametum gussonei* (5330 "Thermo-Mediterranean and pre-desert scrub"), while the second group (B) is split into 2 sub-clusters: the first (B1) is characterized by a chamaephytic vegetation ascribed to the *Crucianellion maritimae* dominated by *Ononis hispanica* subsp. *ramosissima* on disturbed retrodunes (B1.1) or *Helianthemum lippii* on fossil/inner dunes (B1.2) (2210 "*Crucianellion maritimae* fixed beach dunes"), while the second (B2) is featured by annual plant communities dominated by *Muscari gussonei* (2230 "*Malcolmietalia* dune grasslands").

The values of species richness and diversity index (Tab. 1; 63 species/41 relevés) indicate that the woody plant communities (cluster A) have a moderate diversity with an average species richness of 14 and an average Shannon-Wiener index (H) of 2.5 (J=0.95). Both these values slightly decrease in the chamaephytic vegetation with *Ononis hispanica* subsp. *ramosissima* (cluster B1.1) with an average of 12 species and H=2.36 (J=0.95). The values slightly increase both in the chamaephytic vegetation with *Helianthemum lippii* (cluster B1.2) with an average of 16 species and H=2.65 (J=0.96) and in the annual plant communities dominated by *M. gussonei* (B2) with an average of 16 species and H=2.66 (J=0.97).

As concerns our survey exclusively focused on the therophytic plant community dominated by *M. gusso-*

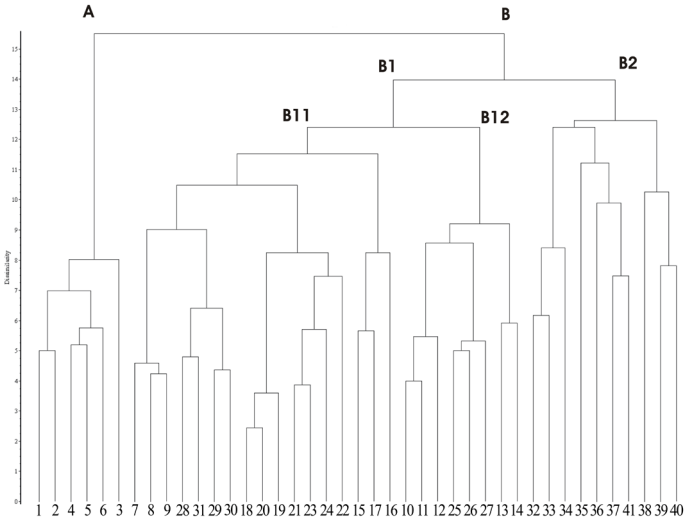

Fig. 2 - Cluster analysis (UPGMA euclidean) (41 random relevés).

Tab. 1 - Phytosociological surveys (41 relevés/63 species). Localities: PA (Poggio Arena), CC (Cava Cammarata), PV (Pineta di

Life form	Distribution	Localities	PA	PA	PA	PA	PA	PA	CC	CC	CC	CC	CC
		Relevé number	1	2	3	4	5	6	10	11	12	13	14
		Surface (mq)	100	100	100	50	50	50	50	50	50	50	50
		Coverage(%)	90	90	90	90	95	90	85	85	80	85	80
		Slope (°)	25	10	15	15	20	20	35	30	25	30	30
		Aspect	S	S	S	S	S	S	SO	SO	SO	SO	SO
		Altitude (m)	12	16	14	15	17	14	21	22	23	22	23
		Distance of sea (m)	132	151	135	140	130	133	473	484	488	480	481
		No. species	15	14	15	16	12	12	13	15	12	18	21
		Vegetation height (average) m	3	3	3	3	3	3	40	40	45	40	40
		Shannon_H	2.582	2.513	2.565	2.657	2.354	2.354	2.441	2.579	2.369	2.793	2.961
		Evenness_e^H/S	0.8819	0.8813	0.8668	0.891	0.877	0.877	0.8835	0.8788	0.8905	0.9072	0.9197
		Equitability_J	0.9536	0.9521	0.9472	0.9584	0.9472	0.9472	0.9517	0.9523	0.9534	0.9663	0.9725
T scap	Med.	Euphorbia terracina L.	+	+	1	+	1	+	1	2	2	1	2
T scap	Med.	Erodium laciniatum (Cav.) Willd.	.	.	+	+	+	1	1	+	1	+	+
G bulb	End. cam.-pach.	Muscari gussonei (Parl.) Nyman	+	+	+	+	+	+	+	1	+	2	+
H caesp	Med.	Ononis hispanica L. subsp. ramosissima (Desf.) Förther & Podlech	.	.	.	.	.	.	+	1	+	1	1
H scap	Med.	Centaurea sphaerocephala L.	1	1	2	1	+	+	+	+	+	1	+
T scap	SO-Med.	Cutandia divaricata (Desf.) Asch. ex Barbey	.	.	.	.	.	.	+	+	+	+	+
H bien	O Med.	Daucus carota L. subsp. maritimus (Lam.) Batt. in Batt. & Trab.	.	.	.	+	.	+	+	+	.	1	+
Ch suffr	O Med.	Rhodalsine geniculata (Poir.) F. N. Williams	2	1	1	1	2	1	1	+	+	.	.
T scap	Med.	Anisantha rigida (Roth) Hyl.	.	.	.	+	+	.	.	.	.	+	+
H scap	Med.	Lobularia maritima (L.) Desv.	+	+	+	+	+	.	+	+	1	1	1
Ch frut	S Med.	Launaea fragilis (Asso) Pau	+	.	.	.	.	.	.	+	.	1	1
T scap	Med.	Rumex bucephalophorus L.	+	+	+	.	.	.	.	.	.	+	+
H scap	Med.	Alkanna tinctoria Tausch	.	.	.	.	.	.	.	.	.	.	.
P caesp	End. cam.-pach.	Retama raetam (Forssk.) Webb & Berth. subsp. gussonei (Webb) Greuter in Greuter & Raus	4	4	3	4	4	4	.	.	+	.	.
T caesp	Med.	Vulpia fasciculata (Forssk.) Fritsch	.	.	.	.	.	.	.	.	.	.	.
T scap	Med.	Lagurus ovatus L.	.	.	.	+	+	.	.	.	.	+	1
T scap	Med.	Silene colorata Poir.	.	.	.	+	.	+	.	.	.	.	.
H scap	O Med.	Cachrys libanotis L.	.	.	.	.	.	.	.	.	.	+	+
Ch suffr	S Med.	Helianthemum lippii (L.) Dum.-Cours.	.	.	.	.	.	.	4	4	3	4	3
H bien	Med.	Scolymus hispanicus L.	.	.	.	.	.	.	+	+	.	.	.
T scap	Med.	Corynephorus divaricatus(Pourr.) Breistr.	.	.	.	.	.	.	.	.	.	.	.
T scap	S Med.	Hormuzakia aggregata (Lehm.) Guşul.	+	+	+	.	.	.	.	.	.	.	.
T scap	Med.-Iran.-Tur.	Senecio glaucus L. subsp. coronopifolius (Maire) C. Alexander	.	.	.	.	.	.	.	.	.	.	.
NP	Med.	Asparagus acutifolius L.	+	+	+	+	.	+	.	.	.	.	.
G rhiz	Med.	Asphodelus ramosus L.	.	.	.	.	.	.	.	.	.	.	+
T scap	Med.-Iran.-Tur.	Brassica tournefortii Gouan	.	.	.	.	.	.	.	.	.	.	.
T scap	Med.	Ononis diffusa Ten.	.	.	.	+	.	.	.	.	.	+	+
H bien	C Med.	Seseli tortuosum L. subsp. maritimum (Guss.) Brullo C, Brullo, Giusso & Sciandrello	.	.	.	.	.	.	.	.	.	.	+
NP	Med.	Asparagus horridus L.	1	+	2	1	+	2	.	.	.	.	.
Ch suffr	Nat. (Sudafr.)	Carpobrotus edulis (L.) N. E. Br.	.	.	.	.	.	.	.	.	+	.	.
H caesp	Med.-Trop.	Hyparrhenia hirta (L.) Stapf in Prain	.	.	.	.	.	.	.	.	.	.	.
H caesp	Nat.	Saccharum spontaneum L. subsp. aegyptiacum (Willd.) Hack.	.	.	.	.	.	.	.	+	.	.	.
T scap	Med.	Stipa capensis Thunb.	.	.	.	.	.	.	+	+	+	.	.
G bulb	Med.	Charybdis pancration (Steinh.) Speta	.	.	.	.	.	.	.	.	.	.	.
G rhiz	Med.	Cyperus capitatus Vandel.	.	.	.	.	.	.	.	.	.	.	.
G rhiz	Boreo-Trop.	Imperata cylindrica (L.) Raeusch.	.	.	.	.	.	.	.	.	.	.	.
T scap	O Med.	Medicago italica (Mill.) Grande subsp. tornata (L.) Emb. & Maire	.	.	.	.	.	.	.	.	.	.	.
T scap	Med.	Andryala integrifolia L.	.	.	.	.	.	.	.	.	.	.	.
T scap	Cosmop.	Avena barbata Pott ex Link	.	.	.	.	.	.	.	.	.	.	.
H ros	S Med.	Carlina gummifera (L.) Less.	.	.	.	.	.	.	.	.	.	.	.
T scap	O Med.	Coronilla repanda (Poir.) Guss.	.	.	.	.	.	.	.	.	.	+	+
NP caesp	Med.	Ephedra fragilis Desf.	2	1	4	2	1	1	.	.	.	.	.
Ch suffr	Med.	Lotus creticus L.	.	+	.	.	.	.	.	.	.	1	+
NP	Med.-Iran.-Tur.	Lycium intricatum Boiss.	1	2	2	1	1	+	.	.	.	.	.
T scap	Med.	Maresia nana (DC.) Batt.	.	.	.	.	.	.	.	.	.	.	.
T scap	End. sic.-pel.	Plantago afra L. subsp. zwierleinii (Nicotra) Brullo	.	.	.	.	.	.	.	.	.	.	.
H scap	Med.	Bituminaria bituminosa (L.) E. H. Stirton	.	.	.	.	.	.	+	+	.	.	1
Ch suffr	Med.	Crucianella maritima L.	.	.	.	.	.	.	.	.	.	.	.
T scap	C Med.	Echium sabulicolum Pomel	.	.	.	.	.	.	.	.	.	+	+
T scap	E Med.	Lotus halophilus Boiss. & Spruner	.	.	.	.	.	.	.	.	.	.	.
G bulb	E Med.	Ornithogalum gussonei Ten.	.	.	.	.	.	.	.	.	.	.	.
T scap	Med.	Polycarpon tetraphyllum (L.) L.subsp. diphyllum (Cav.) O. Bolòs & Font Quer	.	.	.	.	.	.	.	.	.	.	.
T scap	Med.	Urtica membranacea Poir. in Lam.	+	+	.	.	.	.	.	.	.	.	.
Ch suffr	Med.	Ajuga iva (L.) Schreb.	.	.	.	.	.	.	.	.	.	.	.
H bien	Med.	Asphodelus fistulosus L.	.	.	.	.	.	.	.	.	.	.	.
T scap	Med.	Centaurium tenuiflorum (Hoffmanns. & Link) Fritsch in Mitt.	.	.	.	.	.	.	.	.	.	.	.
T scap	Med.-Iran.-Tur.	Dasypyrum villosum (L.) P. Candargy	.	.	.	.	.	.	.	.	.	.	.
T scap	Med.	Medicago littoralis Rohde ex Loisel.	.	.	.	.	.	.	.	.	.	.	.
G rhiz	Cosmop.	Phragmites australis (Cav.) Trin. ex Steud.	.	.	.	.	.	.	.	.	.	.	.
Ch frut	Med.	Prasium majus L.	.	.	+	.	.	.	.	.	.	.	.
T scap	Med.	Pseudorlaya pumila (L.) Grande	.	.	.	.	.	.	.	.	.	.	.
NP	Nat.	Rumex lunaria L.	+	.	.	.	.	.	.	.	.	.	.
T scap	End. cam.-pach.	Torilis nemoralis (Brullo) Brullo & Giusso	.	.	+	.	.	.	.	.	.	.	.

nei, it was possible to highlight some relevant floristic variations strictly linked to the ecological gradients, thus confirming the high variability detected for the psammophilous therophytic communities from the whole Mediterranean area (Diez Garretas *et al*., 2003; Costa *et al*., 2011; Tomaselli *et al*., 2011; Conti *et al*., 2017).

Our assumption of differentiation of the *M. gussonei* ephemeral plant community (*Vulpio-Leopoldietum gussonei*), along a gradient of ecological conditions ranging from the coast to inner areas, highlighted by the floristic diversity, is better supported by inserting some ecological parameters and performing a canonical component analysis (CCA).

The result of the CCA performed on the permanent plots (48 *taxa*/10 plots) (Tab. 2), shows a main gradient of distance of the sea, floristic richness and altitude on

Vittoria), SL (Santa Lucia), MI (C.da Mignechi), PM (Passo Marinaro), BG (Biviere di Gela).

PV	PV	PV	SL	SL	SL	MI	MI	MI	PM	PM	PM	PV	PV	PV	PV	BG	BG	BG	BG	PA	PA	PA	SL	CC	MI	PM	PV	PV	BG
25	**26**	**27**	**7**	**8**	**9**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**
20	20	20	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	4	4	4	4	4	4	4	4	4	4
90	95	90	90	90	90	80	85	80	70	75	80	85	80	80	85	90	80	80	90	55	70	80	90	85	85	80	85	80	80
10	10	10	20	25	25	5	5	5	5	5	2	5	5	5	5	5	5	5	5	5	5	10	5	20	2	2	2	5	5
E	E	SE	SE	SE	SE	SO	SO	SO	E	E	SE	NE	E	SE	SE	N	N	N	N	S	S	S	SE	SO	SO	E	NE	SE	N
54	55	54	17	18	18	10	11	10	31	33	31	51	52	53	53	12	12	12	13	6	7	10	18	22	10	32	52	58	12
4985	4985	4985	519	566	606	580	582	580	1420	1420	1420	4985	4985	4985	4985	1400	1400	1400	1400	115	117	142	557	491	565	1420	4985	4962	1400
16	15	19	11	10	11	15	18	16	8	6	8	14	13	14	15	13	12	13	12	15	14	15	21	16	11	18	18	19	13
40	40	40	50	45	55	35	40	40	40	45	50	40	45	45	45	60	50	60	50	16	15	30	35	30	30	20	20	25	25
2.642	2.602	2.855	2.275	2.192	2.283	2.594	2.768	2.694	1.967	1.624	1.967	2.546	2.469	2.554	2.606	2.441	2.326	2.441	2.384	2.621	2.524	2.666	2.957	2.648	2.278	2.771	2.826	2.871	2.484
0.8779	0.899	0.914	0.8847	0.8957	0.8914	0.8926	0.8851	0.9248	0.8941	0.8457	0.8941	0.9116	0.9088	0.9181	0.9028	0.8835	0.8534	0.883	0.9043	0.9164	0.8914	0.9586	0.916	0.8828	0.8874	0.8873	0.9377	0.9292	0.9218
0.953	0.9607	0.9695	0.9489	0.9522	0.9521	0.958	0.9578	0.9718	0.9462	0.9065	0.9462	0.9649	0.9627	0.9676	0.9622	0.9517	0.9362	0.9515	0.9595	0.9678	0.9564	0.9844	0.9712	0.955	0.9502	0.9586	0.9778	0.9751	0.9682
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axis 1 and a secondary gradient of texture and vegetation cover on axis 2 (Fig. 3). The CCA clearly separates 3 habitat types for *Muscari gussonei*, each with a specific ecology. The first (P7, P8, P9), well-separated along axis 1, groups the community of the inner/fossil dunes featured by a high floristic richness and growing on consolidated sandy soils. On the left (Axis 1) we find the community (P1, P2, P3) that prefers flat stands in between the lower dunes with rather incoherent substrates (white dunes-retrodunes). This feature is associated to a significant floristic poorness. At the bottom of axis 2, the community (P4, P5, P6, P10) is linked to grey dunes with high concentrations of clay, a moderate floristic diversity and a higher cover values.

In addition, CCA diagram shows the position of each species related to the different plot (they can be identi-

Tab. 2 - Permanent plots (10 plots/48 species).

Life form	Distribution	No. Species		2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
			Localities	Poggio Arena			Poggio Arena			Poggio Arena			Macconi Santa Lucia			Macconi Cava Cammarata			Macconi Mignechi			Passo Marinaro			Pineta Vittoria			Pineta Vittoria			Biviere Gela		
			Plots number	P1	P1	P1	P2	P2	P2	P3	P3	P3	P4	P4	P4	P5	P5	P5	P6	P6	P6	P7	P7	P7	P8	P8	P8	P9	P9	P9	P10	P10	P10
			Surface (mq)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
			Coverage (%)	55	55	55	70	70	70	80	80	80	90	90	90	85	85	85	85	85	85	80	80	80	85	85	85	80	80	80	80	80	80	80	80	80
			Slope (°)	5	5	5	5	5	5	10	10	10	5	5	5	20	20	20	2	2	2	2	2	2	2	2	2	5	5	5	5	5	5	5	5	5
			Aspect	S	S	S	S	S	S	S	S	S	SE	SE	SE	SO	SO	SO	SO	SO	SO	E	E	E	NE	NE	NE	SE	SE	SE	N	N	N	N	N	N
			Soil depth	40	40	40	45	45	45	54	54	54	45	45	45	55	55	55	40	40	40	15	15	15	22	22	22	28	28	28	40	40	40	40	40	40
			Altitude (m)	6	6	6	7	7	7	10	10	10	18	18	18	22	22	22	10	10	10	32	32	32	52	52	52	58	58	58	12	12	12	12	12	12
			Distance of sea (m)	115	115	115	117	117	117	142	142	142	557	557	557	491	491	491	565	565	565	1420	1420	1420	4985	4985	4985	4962	4962	4962	1400	1400	1400	1400	1400	1400
			No. species	15	15	16	14	18	18	15	17	17	21	21	20	16	19	20	11	14	15	20	18	17	18	22	20	19	21	19	13	12	12	13	12	12
			No. *M. gussonei*	**46**	**39**	**42**	**124**	**88**	**92**	**41**	**36**	**38**	**12**	**8**	**10**	**16**	**16**	**25**	**99**	**82**	**102**	**4**	**2**	**6**	**56**	**51**	**86**	**132**	**121**	**128**	**23**	**18**	**21**	**23**	**18**	**21**
				15	15	16	14	18	18	15	17	17	21	21	20	16	19	20	11	14	15	20	18	17	18	22	20	19	21	19	13	12	12	13	12	12
			Coordinates	N 37° 05' 39.1"			N 37° 05' 39.0"			N 37° 05' 39.5"			N 37° 02' 32.9"			N 37° 02' 17.2"			N 37° 01' 12.5"			N 36° 51' 33.6"			N 36° 53' 58.6"			N 36° 53' 59.3"			N 37° 00' 58.9"		
				E 014° 09' 49.4"			E 014° 09' 50.0"			E 014° 09' 51.2"			E 014° 17' 49.8"			E 014° 18' 09.8"			E 014° 19' 33.8"			E 014° 27' 51.7"			E 014° 29' 19.4"			E 014° 29' 18.2"			E 014° 20' 33.7"		
G bulb	End. cam.-pach.	1	Muscari gussonei (Parl.) Nyman	1	1	1	2	2	2	1	1	1	+	+	+	1	1	1	3	2	3	+	+	+	1	1	2	2	2	2	1	1	1
T scap	Med.-Iran.-Tur.	2	Senecio glaucus L. subsp. coronopifolius (Maire) C. Alexander	+	1	+	+	+	1	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+
T scap	Med.	3	Pseudorlaya pumila (L.) Grande	+	+	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
T scap	Med.	4	Ononis diffusa Ten.	.	.	.	.	.	.	.	.	.	1	1	+	.	.	.	.	.	.	.	.	.	1	1	2	2	2	2	1	1	1	1	1	1
T scap	End. sic.-pel.	5	Plantago afra L. subsp. zwierleinii (Nicotra) Brullo	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	+	1	1	1	1	1	1	.	.	.	.	.	.
T scap	O Med.	6	Coronilla repanda (Poir.) Guss.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	3	2	2	2	1	2	2	.	.	.	.	.	.
T scap	Med.	7	Maresia nana (DC.) Batt.	1	+	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
T scap	Med.-Iran.-Tur.	8	Brassica tournefortii Gouan	.	.	.	.	.	.	.	.	.	1	1	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1	.	.	.
H scap	Med.	9	Alkanna tinctoria Tausch	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	1	1	1	1	+	1	1	.	.	.	.	.	.
T scap	S Med.	10	Hormuzakia aggregata (Lehm.) Guşul.	+	+	1	.	+	+	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
T scap	Med.	11	Erodium laciniatum (Cav.) Willd.	1	1	1	1	1	1	+	1	1	1	1	1	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	3	3	3	3	3	3
T scap	SO-Med.	12	Cutandia divaricata (Desf.) Asch. ex Barbey	+	1	1	+	1	1	+	1	1	3	3	2	2	3	2	2	3	2	+	1	1	1	1	2	+	1	1	1	2	2	1	2	2
T caesp	Med.	13	Vulpia fasciculata (Forssk.) Fritsch	+	+	+	+	+	.	+	+	.	+	1	1	+	1	1	+	1	1	1	1	+	2	2	1	+	1	+	1	1	+	1	1	+
T scap	Med.	14	Anisantha rigida (Roth) Hyl.	.	.	+	.	.	.	1	+	+	2	3	3	3	3	3	1	2	1	.	.	.	+	1	+	.	+	.	1	2	1	.	.	.
T scap	Med.	15	Polycarpon tetraphyllum (L.) L.subsp. diphyllum (Cav.) O. Bolòs & Font Quer	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	.	.	.	.	.	.
T scap	Med.	16	Medicago littoralis Rohde ex Loisel.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
T scap	E Med.	17	Lotus halophilus Boiss. & Spruner	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	+	+	.	.	.	.	.	.
T scap	Med.	18	Silene colorata Poir.	.	.	.	+	+	+	.	.	.	+	1	+	+	+	+	1	+	1	.	.	.	+	+	+	.	+	+	+	+	1	+	+	1
T scap	Med.	19	Rumex bucephalophorus L.	3	3	2	3	4	3	1	1	1	+	1	1	1	1	1	.	.	.	1	1	1	+	+	+	1	1	1	.	.	.	.	.	.
T scap	Med.	20	Andryala integrifolia L.	.	.	+	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	+	+	.	.	.	.	+	+	.	.	.	.	.	.	.
T scap	O Med.	21	Medicago italica (Mill.) Grande subsp. tornata (L.) Emb. & Maire	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
T scap	Med.	22	Corynephorus divaricatus(Pourr.) Breistr.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	1	1	+	+	1	1	.	.	.	.	.	.
T scap	C Med.	23	Echium sabulicolum Pomel	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.
T scap	Med.	24	Lagurus ovatus L.	+	1	+	+	+	+	+	+	+	1	1	+	.	+	+	+	1	+	+	1	1	+	+	+	+	+	+	+	1	+	.	.	.
T scap	Med.	25	Euphorbia terracina L.	+	+	+	+	+	+	2	2	2	+	1	1	.	1	1	+	1	1	+	1	1	.	.	.	+	+	+	+	1	1	.	.	.
H scap	Med.	26	Lobularia maritima (L.) Desv.	+	+	+	.	+	+	.	+	1	+	1	1	+	+	1	.	.	.	+	+	1	.	+	+	.	.	.	.	.	.	.	.	.
H caesp	Med.	27	Ononis hispanica L. subsp. ramosissima (Desf.) Förther & Podlech	.	.	.	.	.	.	.	.	.	+	+	1	1	1	1	1	1	+	+	1	1	+	+	+	.	.	.	1	1	1	.	.	.
Ch suffr	O Med.	28	Rhodalsine geniculata (Poir.) F. N. Williams	1	1	+	.	+	+	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	.	.	.	.	.	.
Ch suffr	S Med.	29	Helianthemum lippii (L.) Dum.-Cours.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ch suffr	Med.	30	Lotus creticus L.	.	.	.	.	.	.	.	.	.	2	1	1	+	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
H scap	Med.	31	Centaurea sphaerocephala L.	.	+	+	+	1	1	1	2	2	.	.	.	.	.	.	.	.	.	+	+	1	.	.	.	.	.	.	.	.	.	.	.	.
H scap	O Med.	32	Cachrys libanotis L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	.	+	+	+	1	1	.	.	.	.	.	.
H bien	O Med.	33	Daucus carota L. subsp. maritimus (Lam.) Batt. in Batt. & Trab.	+	+	+	+	+	+	+	1	+	+	1	1	1	1	1	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
G rhiz	Med.	34	Cyperus capitatus Vandel.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ch suffr	Nat. (Sudafr.)	35	Carpobrotus edulis (L.) N. E. Br.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
G rhiz	Boreo-Trop.	36	Imperata cylindrica (L.) Raeusch.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ch frut	S Med.	37	Launaea fragilis (Asso) Pau	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.
P caesp	End. cam.-pach.	38	Retama raetam (Forssk.) Webb & Berth. subsp. gussonei (Webb) Greuter in Greuter & Raus	+	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
NP	Med.	39	Asparagus horridus L.	.	.	.	+	+	+	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
G rhiz	Cosmop.	40	Phragmites australis (Cav.) Trin. ex Steud.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
T scap	Cosmop.	41	Avena barbata Pott ex Link	.	.	.	.	.	.	.	.	.	+	+	+	+	1	1	.	+	+	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.
T scap	Med.-Iran.-Tur.	42	Dasypyrum villosum (L.) P. Candargy	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
G bulb	E Med.	43	Ornithogalum gussonei Ten.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ch suffr	Med.	44	Ajuga iva (L.) Schreb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.
T scap	Med.	45	Centaurium tenuiflorum (Hoffmanns. & Link) Fritsch in Mitt.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
H bien	Med.	46	Asphodelus fistulosus L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.
T scap	Med.	47	Stipa capensis Thunb.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	+	+	.	.	.	.	.	.
H caesp	Med.-Trop.	48	Hyparrhenia hirta (L.) Stapf in Prain	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	1	1	.	.	.	.	.	.

Tab. 3 - Soil analysis of the permanent plots.

Plot	Site	Clay (%)	Silt (%)	Sand (%)	pH	CE (mS/cm)	Nitrogen (%)	Organic matter	Total limestone (%)	Mg (ppm)	Na (ppm)	K (ppm)	Ca (ppm)
1	**Poggio Arena**	3.45	7.85	88.7	7.32	65	0.08	1.5	18	0.01	0.02	0.09	0.49
2	**Poggio Arena**	9.15	5.85	85	7.28	56.4	0.04	0.8	18	0.01	0.01	0.11	0.3
3	**Poggio Arena**	6.8	9.85	83.35	7.31	62	0.04	0.7	18	0.01	0.01	0.13	0.3
4	**Santa Lucia**	12.6	5.2	82.2	7.88	70.7	0.06	1.1	19	0.01	0.01	0.14	0.39
5	**Cava Cammarata**	10.5	15	74.5	7.9	74.1	0.06	1.2	18	0.01	0.01	0.15	0.36
6	**Mighechi**	11.65	4.95	83.4	7.88	65.8	0.02	0.4	16	0.01	0.01	0.16	0.26
7	**Passo Marinaro**	11.2	5.65	83.15	7.83	72.7	0.07	1.5	16	0.01	0.05	0.18	0.74
8	**Pineta Vittoria**	7.2	9.85	82.95	7.92	58.8	0.06	1.1	10	0.01	0.01	0.18	0.34
9	**Pineta Vittoria**	4.3	2.7	93	7.91	60	0.04	0.8	14	0.01	0.01	0.19	0.42
10	**Biviere Gela**	7.05	18.85	74.1	7.1	62.3	0.04	0.7	18	0.01	0.01	0.19	0.49

fied by the number of the third column in Tab. 2). Thus, some species, as *Muscari gussonei*, *Vulpia fasciculata*, *Erodium laciniatum*, *Cutandia divaricata*, *Anisantha rigida*, occupy a central position revealing a wider ecological amplitude and they are common in the entire macro-community; on the contrary, at the extremities of the axes we can see several species with a narrow ecological niche characterizing the three different habitats, such as *Maresia nana*, *Brassica tournefortii* and *Hormuzakia aggregata* for the white dunes, *Plantago afra* subsp. *zwierleinii*, *Coronilla repanda* and *Alkanna tinctoria* for inner dunes.

The Spearman correlation shows a significant positive correlation between species richness and altitude ($r = 0.78$; $p < 0.05$), as well as for the sea distance ($r = 0.66$). In addition, the numerical abundance of *Muscari gussonei* individuals is negatively correlated to altitude ($r = -0.76$; $p < 0.05$) and distance to the sea ($r = 0.93$; $p < 0.05$).

Distribution range, population structure and size

M. gussonei disappeared from many sites where it was recorded in the past, such as Sampieri, Marzamemi, Portopalo, Marina della Marza, S. Maria del Focallo, Capo Isola delle Correnti, Macchitella di Gela, *etc*.

Our investigations allowed to confirm its occurrence just in 4 macro-sites (Fig. 4): 1. Poggio Arena (Gela); 2. Macconi di Gela (a. Santa Lucia, b. Cava Cammara-

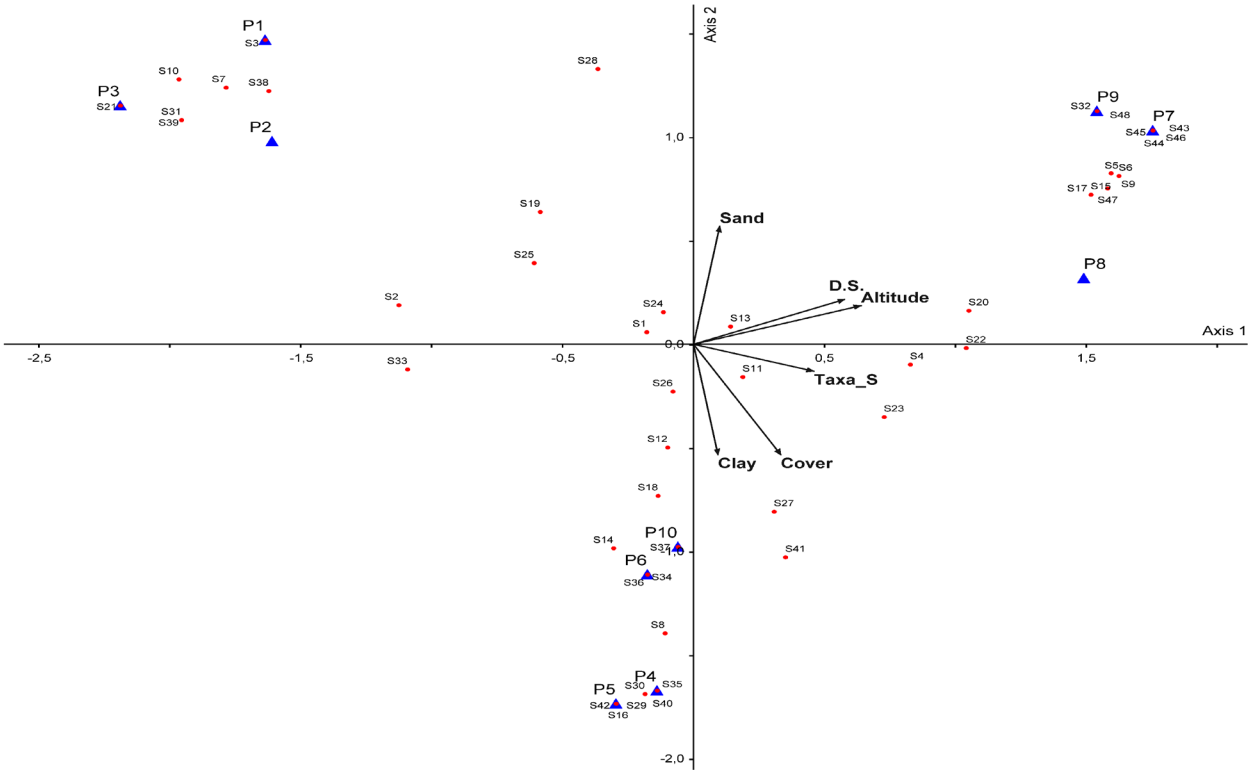

Fig. 3 - CCA (10 plots). Total variance ("inertia") in the species data: 1.8094. Eigen-value Axis 1, 0.42; Axis 2, 0.34; Axis 3, 0.25. Variance in species data % of variance explained Axis 1, 23.4; Axis 2, 19.1; Axis 3, 14.2. Cumulative % explained Axis 1, 23.4; Axis 2, 42.5; Axis 3, 56.7. Each species is identified with the same number of Tab. 2. Acronyms: P= Plot (1-10, see Fig. 1), D.S. = distance of the sea; Taxa_S = floristic richness; Cover = vegetation cover.

ta, c. Industrial site, d. Biviere di Gela, e. C.da Mignechi); 3. Ragusa (a. Passo Marinaro, b. Cava Randello, c. Cammarana, d. Refriscolaro, e. Branco Piccolo); 4. Pineta di Vittoria (a. C.da Brancato, b. C.da Gerbe).

The site hosting the largest population (about 1,500 mature individuals spread over an area of 5,000 m^2, is Poggio Arena (site 1), a coastal dunal system (about 45 m high) close to the sea rather well preserved. The population from Macconi di Gela (site 2) is really fragmented mainly due to the intensive agricultural activities. Currently, a total of five sub-populations were identified within site 2: a. Santa Lucia with about 120 plants in an area of about 800 m^2; b. Cava Cammarata with approximately 340 plants in a small area of about 500 m^2 whose survival is severely threatened by quarrying activities; c. Industrial site with approximately 50 plants in an area of about 810 m^2; d. Biviere di Gela with about 50 plants in an area of about 500 m^2; e. C.da Mignechi with about 420 plants in an area of 690 m^2. The just mentioned areas were, in the past, the most important sites with *M. gussonei*, as highlighted by Garbari & Di Martino (1972). In addition to the above mentioned threats, site 2 is seriously threatened by two invasive plants, namely *Carpobrotus edulis* (L.) N.E. Br. and *Saccharum spontaneum* L. subsp. *aegyptiacum* (Willd.) Hack. The Cava Randello-Punta Braccetto population (site 3) is also very disturbed, particularly for the intensive agricultural activities and overgrazing. A total of five sub-populations were surveyed within site 3: a. Passo Marinaro, 80 mature individuals spread over an area of about 710 m^2, severely disturbed by rabbits; b. Cava Randello, less than 70 plants were recorded in an area of about 800 m^2; c. Cammarana, 60 plants were found in 800 m^2; d. Refriscolaro, 50 plants were surveyed in 700 m^2; e. Branco Piccolo, 30 plants spread over an area of about 480 m^2.

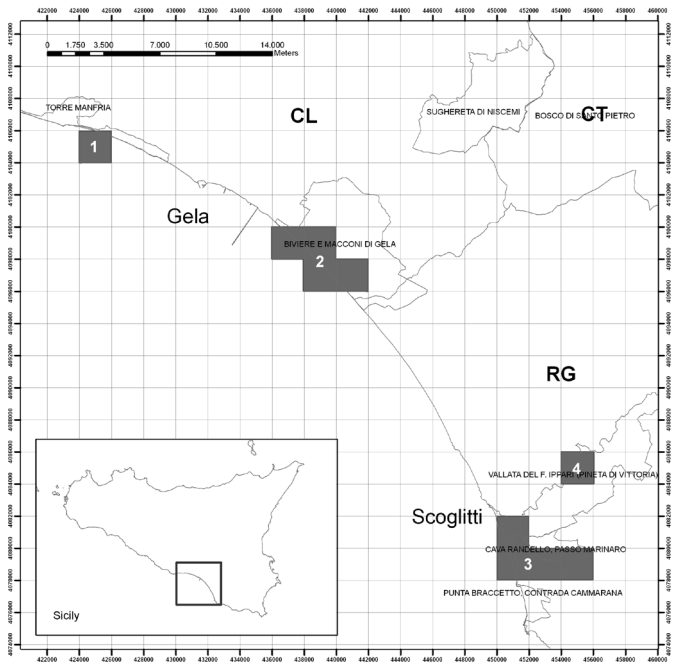

Fig. 4 - Geographical distribution (AOO according to IUCN 2017a) of *Muscari gussonei* (grid of 2 x 2 km).

Lastly, the Pineta di Vittoria population (site 4) is the innermost stand, localized at 50 m a.s.l., about 6 km far from the coast. This is the only population which seems to be in a phase of recovery, likely due to the crop reduction. In particular, less than 820 mature individuals were recorded in C.da Brancato (820 m^2), but the abandonment of cultivated fields is favouring the expansion of *M. gussonei* populations, while in C.da Gerbe about 80 plants were surveyed in an area of 500 m^2, interspersed with the bushes of *Retama raetam* subsp. *gussonei*.

Considering the data about the current distribution of *M. gussonei*, more than 50% of the current population can be found at Poggio Arena (Fig. 4, site 1). In the absence of disturbing factors, the number of plants growing at Poggio Arena is destined to increase, especially for the optimal conditions of the site and the number of mature individuals. Whereas, the Macconi di Gela population is declining. The main disturbance is the continuous physical modification of the dunes chiefly made for creating new areas suitable for cultivations or service roads, all activities that lead to the a drastic reduction and fragmentation of the natural habitat of *M. gussonei*. Furthermore, the overuse of nitrates favours some invasive species, as *Saccharum spontaneum* subsp. *aegyptiacum* and *Carpobrotus edulis*, thus representing another serious threat. The population from Cava Randello-Punta Braccetto is also strongly altered. In fact, this population is also declining due to overgrazing, fires, and rabbits. Only for the for the Pineta di Vittoria population a positive trend has been detected, being the general ecological conditions of the area slightly improving (Tab. 4).

According to the IUCN Red List categories and criteria (2001), the population of *M. gussonei* occupies an area (AOO) of about 40 km^2 (4 location, Fig. 4). Thus, considering the small population size, the distance among different populations, as well as the several threats, we may conclude that the distribution area of *M. gussonei* is highly fragmented and at risk of further reduction.

The current conservation status of *M. gussonei*, according to Conti *et al*. (1997) is endangered (EN). Based on the field investigations carried out in the present survey, we confirm the IUCN rank proposed by Brullo *et al*. (2010), EN B2 ab (ii, iii, iv).

Discussion

Almost 2 centuries ago, Gussone (1827) recorded *M. gussonei* along the sandy coast of Sicily, from Gela to Capo Passero (southern-easternmost point of Sicily). During the last decades, southern Sicily has been dra-

Tab. 4 - The four locations where *M. gussonei* has been located, with number of individuals, area, altitude range and identified threats (IUCN, 2017b).

	Locality	No. *M. gussonei*	Area m^2	Altitude (m)	Threats
1	**Poggio Arena (Manfria, Gela)**	1,500	5,000	6-10	1.3 Tourism & recreation areas; 2.3.1 Nomadic grazing; 6.1 Recreational activities; 7.1.1 Increase in fire frequency/intensity; 8.1 Invasive non-native/alien species (*Saccharum spontaneum* , *Carpobrotus edulis* , *Acacia saligna*)
2	**Macconi Gela**	980	3,300	10-22	2.1.3 Agro-industry farming (greenhouse cultivation); 8.1 Invasive non-native/alien species (*Saccharum spontaneum* , *Carpobrotus edulis* , *Acacia saligna*)
3	**Passo Marinaro (Ragusa)**	290	3,490	32	2.1.3 Agro-industry farming (greenhouse cultivation); 8.1 Invasive non-native/alien species (*Saccharum spontaneum* , *Carpobrotus edulis*)
4	**Pineta Vittoria**	900	1,300	52-58	2.3.1 Nomadic grazing; 7.1.3 Fire; 8.1 Invasive non-native/alien species (*Saccharum spontaneum*)

matically modified, especially due to agricultural over-exploitation (*e.g.* glasshouses) and urban sprawling. Unfortunately, we have not enough and reliable historical data to precisely quantify the population declining for the species, but the high fragmentation of the small and few-numbered populations suggests that *M. gussonei* has suffered a drastic reduction, especially over the past 50 years; probably the currently existing sites may constitute a remnant of a once larger population.

Our surveys allowed to record the presence of about 3,700 mature individuals of *M. gussonei* that are still surviving, despite the above-mentioned threats. Currently, they are unevenly distributed on areas ranging from 200 to 5,000 m^2, at altitudes of 10-85 m a.s.l., on south- to north-facing slopes (0-30°), close to the sea up to 6,000 m towards the inner stands (Tab. 1).

Our study analyses the floristic composition of the *M. gussonei* plant community and clarifies some ecological requirements which are relevant issues for future conservation measures to be implemented in order to preserve such an endangered species.

From the sinecological point of view, according to Brullo & Marcenò (1974), Brullo & Grillo (1985), *Muscari gussonei* chiefly grows in a plant community, named *Vulpio-Leopoldietum gussonei*, typical of semi-fixed or fixed dunes. This association, dominated by annual species, belongs to the *Laguro ovati-Vulpion fasciculatae* Géhu and Biondi 1994, alliance of order *Cutandietalia maritimae* Rivas-Martínez, Dìez-Garretas & Asensi 2002 (Minissale & Sciandrello, 2015). As displayed by our cluster analysis the association grows in different closely related sandy habitats represented by the clearings within the shrubby vegetation (*Asparago horridi-Retametum gussonei* Brullo, Guarino & Ronsisvalle 2000) or woody communities (*Ephedro fragilis-Juniperetum macrocarpae* Bartolo, Brullo & Marcenò 1982). It is also found in the clearings of the *Centaureo-Ononidietum ramosissimae* Br.-Bl. & Frei in Frei 1937, chamaephytic association characterized by *Ononis hispanica* subsp. *ramosissima*.

A more in-depth analysis within the association by the classification of plots (10), using CCA, allowed to highlight three clear groups within the *M. gussonei* community (*Vulpio-Lepoldietum gussonei*), each one with typical species useful to characterize the community as a result of small changes in ecological conditions, as proposed by Biondi (2011). The indicator species for each sub-community are the following: *Maresia nana*, *Brassica tournefortii* and *Hormuzakia aggregata* (instable dunes), *Anisantha rigida* and *Cutandia divaricata* (stable dunes), and *Plantago afra* subsp. *zwierleinii*, *Coronilla repanda* and *Alkanna tinctoria* (inland o fossil dunes).

Moreover, the classification of relevés (wider plots), using cluster analysis (41), displayed three vegetation types where *M. gussonei* grows. The annual plant communities dominated by *Muscari gussonei* (*Vulpio-Leopoldietum gussonei* - 2230 *Malcolmietalia* dune grasslands), woody psammophilous plant communities dominated by *Retama raetam* subsp. *gussonei* (*Asparago-Retametum gussonei* - 5330 Thermo-Mediterranean and pre-desert scrub), and, finally, chamaephitic vegetation with *Ononis hispanica* subsp. *ramosissima* or *Helianthemum lippii* (*Centaureo-Ononidetum ramosissimae*, *Helianthemum lippii* comm. - 2210 *Crucianellion maritimae* fixed beach dunes). These plant communities are related to the vegetation series outlined for the south-eastern Sicily by Bazan *et al*. (2010) and Minissale & Sciandrello (2013).

Concluding, the dune ecosystem of southern Sicily, despite falling within several SCIs, is severely threatened by intensive agriculture, urban sprawl and invasion of alien plants that often lead to the full destruction of these habitats (Campos *et al*., 2004; Sciandrello *et al*., 2015). On the basis of these considerations, it is evident that the conservation measures taken so far have been insufficient and it is therefore necessary to act more effectively. Some potential actions that could be implemented in order to preserve the surviving populations of *M. gussonei* are: 1) to enable a better management of SCIs sites; 2) to start an intensive monitoring plan of the populations; 3) to eradicate invasive plants, such as *Carpobrotus edulis*, *Saccharum spontaneum* subsp. *aegyptiacum*, or *Arundo donax*; 4) to create ecological corridors among different populations (Vandepitte *et al*., 2012); 5) to seed sampling

to reinforce the natural populations or translocate *M. gussonei* to other suitable growing sites. Some of these actions have been implemented during the LIFE project (LIFE11 NAT/IT/000232) at the SCI "Biviere e Macconi di Gela" and SCI "Punta Braccetto, Contrada Cammarana" or during the CARE-MEDIFLORA project (Fenu *et al*., 2017b).

In any case, the presence of protected areas is crucial for ensuring the survival and numerical growth of target species and habitats (Fois *et al*., 2018), as also Prisco *et al*. (2016) highlighted for the Italian sandy coastal environments.

Syntaxonomic scheme

QUERCETEA ILICIS Br.-Bl. ex A. & O. Bolòs 1947
PISTACIO LENTISCI-RHAMNETALIA ALATERNI Rivas-Martínez 1975
Oleo-Ceratonion Br.Bl.1936 em. Rivas-Martínez 1975
Asparago horridi-Retametum gussonei Brullo, Guarino & Ronsisvalle 2000
Juniperion turbinatae Rivas-Martínez 1975 corr. 1987
Ephedro fragilis-Juniperetum macrocarpae Bartolo, Brullo & Marcenò 1982

HELICHRYSO-CRUCIANELLETEA MARITIMAE (Sissingh 1974) Géhu, Rivas-Martínez & Tüxen in Géhu 1975 em. Biondi & Géhu in Géhu & Biondi 1994
CRUCIANELLETALIA MARITIMAE Sissing 1974
Crucianellion maritimae Rivas Goday & Rivas-Martínez 1958
Centaureo-Ononidietum ramosissimae Br.-Bl. & Frei in Frei 1937
Helianthemum lippi comm.

TUBERARIETEA GUTTATAE (Br.-Bl. in Br.-Bl. & al. 1952) Rivas Goday & Rivas-Martínez 1963
CUTANDIETALIA MARITIMAE Rivas-Martínez, Díez-Garretas & Asensi 2002
Laguro ovati-Vulpion fasciculatae Géhu & Biondi 1994
Vulpio fasciculatae-Leopoldietum gussonei Brullo & Marcenò 1974

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