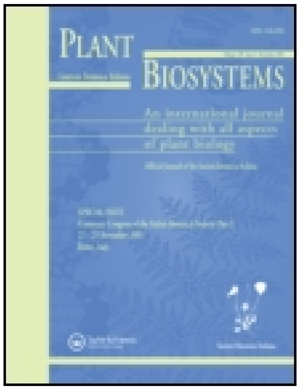

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A relic wood of Juniperus turbinata Guss. (Cupressaceae) in Sicily: Structural and ecological features, conservation perspectives

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A relic wood of *Juniperus turbinata* Guss. (Cupressaceae) in Sicily: Structural and ecological features, conservation perspectives

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Abstract
Juniperus turbinata Guss. (Cupressaceae) is a threatened tree species occurring in the Mediterranean area. It is listed as a vulnerable species in the Red Book of Italian plants and its various communities are included in Annex I of the Habitats Directive 92/43/EEC as a priority habitat for conservation. During field investigations carried out to analyse the plant biodiversity of coastal habitats in southern Sicily, a new interesting population was found. This study aims to characterize this relevant new finding with a marked focus on demography and synecology of the plant community in question in order to define its habitat, assess its conservation status and propose conservation measures. Our data highlight that the juniper is characterized by low turnover population dynamics. In order to understand the role of *J. turbinata* in sandy soil communities of south-eastern Sicily, comparisons of 21 plots (relevés) with 25 established plots in south-eastern Sicily were carried out using cluster analysis and canonical component analysis. This has allowed three different plant communities with different ecological features to be identified.

Keywords: *Juniper stand, population dynamics, vegetation series, conservation, Sicily*

Introduction

Juniperus turbinata Guss. (Cupressaceae) is a monoecious or dioecious tree native to coastal sites of the Mediterranean basin. Adams (2011) places *J. turbinata* as a variety of *Juniperus phoenicea* L. and also includes in this variety *J. phoenicea* L. subsp. *canariensis* (Guyot & Mathou) Rivas-Martínez Wildpret & Perez de Paz. On the basis of morphological and biochemical characteristics, Lebreton and Perez de Paz (2001) separate *J. phoenicea* from *J. turbinata* at the rank of species and place the Canary Island juniper as a subspecies of *J. turbinata*. The two taxa differ also in the flowering pattern (Arista et al. 1997), with *J. turbinata* flowering in October–November, while *J. phoenicea* flowers in February–March.

Juniperus phoenicea is a western European taxon that grows in a wide bioclimatic range from thermo- to supramediterranean semiarid, to humid bioclimatic belts in Spain, southern France and the Italian Maritime Alps (Asensi et al. 2007). *Juniperus turbinata* is found from the infra- to supramediterranean arid to humid bioclimatic belt and is widespread in the Mediterranean region, both in coastal and inland regions (Lebreton & Perez de Paz 2001). In Italy, according to Conti et al. (2005), *J. turbinata* occurs only in Apulia, Basilicata, Calabria, Sicily and Sardinia. Nowadays in Sicily, the populations of *J. turbinata* are extremely rare and isolated. From literature (Gussone 1845; Lojacono Pojero 1904; Gianguzzi et al. 2007; Giardina et al. 2007), *J. turbinata* has been reported several times in Sicily and in nearby islands (Lampedusa, Linosa and Pantelleria), but most of the records are out-dated and currently unconfirmed; moreover, numbers have fallen to include only a few surviving individuals. The most representative populations are mainly localized along the coastal belt of southern Sicily, which represents a very important area from a phytogeographical viewpoint (Bartolo et al. 1982; Brullo et al. 2011). This part of the island is characterized by the occurrence of several endemic or rare species, for the most part circumscribed to this territory (Brullo & Sciandrello 2006; Brullo et al. 2007, 2012). During floristic investigations along the coast of the Sicily, a new and very large juniper-stand (Minissale et al. 2011) was found in the territory of

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Acate (Ragusa), on Pleistocene sands. Such relic population includes several old individuals, more than 6–8 m tall (Figure 1).

In this study, insights into the ecological characteristics of *J. turbinata* stands are provided, with particular attention to population size, population structure and vitality. The structure and composition of the vegetation, as well the phytosociological role played by the juniper-dominated psammophilous communities, were also investigated. The latter is based on a comparison with other smaller juniper stands on the sands of southern Sicily.

Study area

The study area (Figure 2) includes the coastal belt of the southern part of Sicily, from the Gulf of Gela to Capo Passero: this environment is characterized by sand dunes, coastal rocks, wetlands and sandy hills. It is mainly composed of Pleistocene substrates such as calcarenites and sand deposits, which often extend inland for a number of kilometres.

Following the phytogeographic subdivision of Sicily by Brullo et al. (2011), this area, characterized by sand deposits, 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 falls within 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; Scelsi & Spampinato 1998). The study sites are as follows: (1) Piano Pirrera (Acate), (2) Passo Marinaro (Scoglitti), (3) Piano Stella (Gela) and (4) Valle dell'Ippari (Vittoria).

Materials and methods

The population study was carried out at Piano Pirrera, the most representative and best conserved stand. By using a GIS program, the juniper stand was mapped in order to calculate its area. Six plots (10 × 20m) were randomly chosen for measurement and to take an inventory of all *J. turbinata* plants (Figure 3). The number of *J. turbinata* individuals was counted in each plot and each plant labelled. The count does not include seedlings but only established plants such as adults and saplings (seedlings accounted for no more than 10 specimens in two plots only).

Juniperus turbinata has a growth with multiple trunks, so the size of each individual was calculated by measuring the height (H) and the mean crown diameter (D) based on two diameter measurements/individual. The size index of each individual was calculated as the average of its height and crown diameter $[(H + D)/2]$.

Size estimation, following El-Bana et al. (2010), was then used to classify the individuals into 10 size

Figure 1. The relic wood of *Juniperus turbinata* in southern Sicily.

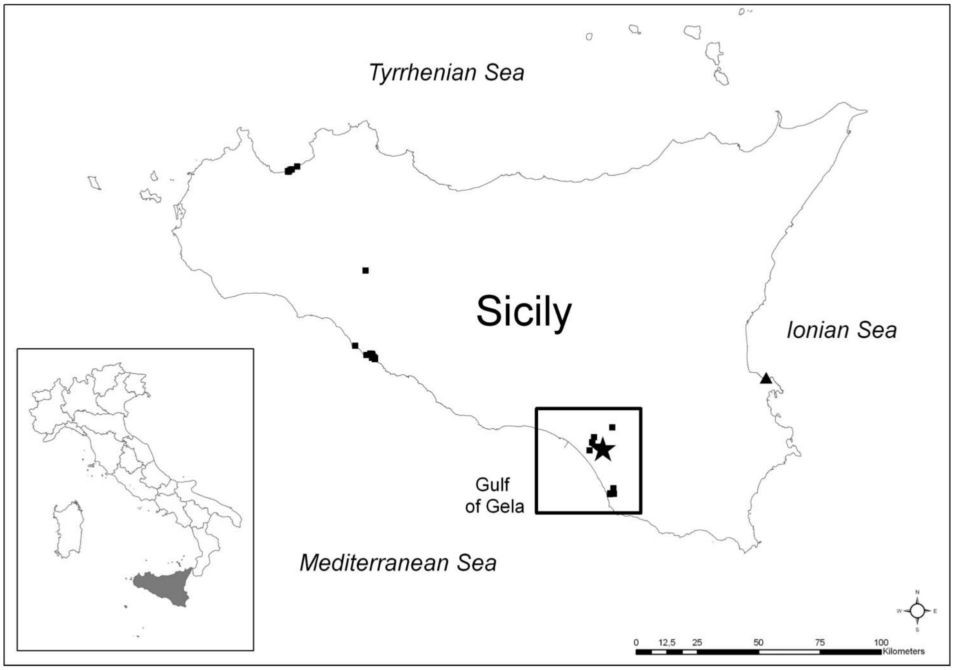

Figure 2. Distribution of *Juniperus turbinata* in Sicily. The large square delimits the study area, the star indicates Piano Pirrera site, small squares known and confirmed sites and the triangle the new site of Brucoli (Syracuse).

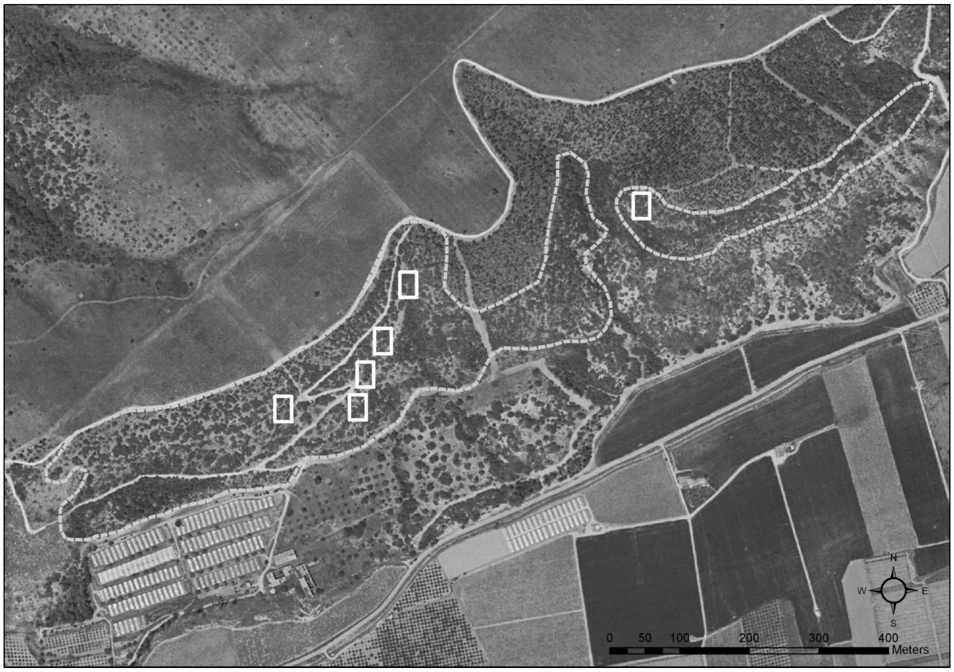

Figure 3. *Juniperus*-stands of Piano Pirrera (Acate) delimited by the two polygons. The rectangles show the sampling plots.

classes divided by 50 cm intervals with the exception of the first class, which ranges from 0 to 1 m and the last, which ranges over 5 m. The absolute and relative frequency of individuals, the mean height, crown diameter and size index per individual in each size class were then determined.

The field work, to analyse the structure and composition of the plant community, was carried out from 2010 to 2012, during which 21 relevés (plots) of vegetation were performed using the Braun-Blanquet phytosociological approach (Braun-Blanquet 1964; Biondi 2011) on the site of Piano Pirrera; (six of these relevés were performed in the six plots used for the population analysis). Other relevés were taken from Bartolo et al. (1982), Brullo et al. (1993), Minissale and Sciandrello (2005) and Brullo et al. (2008).

Numerical analysis (Cluster Analysis – UPGMA method, Chord coefficient) of relevés was performed using the program package SYN-TAX 2000 (Podani 2001). Environmental gradients and plant communities were examined with canonical component analysis (CCA), using the "PC-ORD", v4.34 software. The original Braun-Blanquet sampling scale was transformed into the ordinal scale according to Van der Maarel (1979). For the nomenclatural treatment of the species, Giardina et al. (2007) and Raimondo and Spadaro (2009) were followed, while phytosociological nomenclature followed Rivas-Martínez et al. (2001) and Brullo et al. (2002).

The soil classification followed Fierotti et al. (1989), which for this area recognizes two types: type 1 is a xeropsamment of consolidated dunes (txc), type 2 is a lithic rhodoxeralf formed of calcarenites and incoherent deposits (lri).

Results

Demographic structure of Piano Pirrera population

On the basis of photo-interpretation and calculation functions of the GIS, the pure juniper stand covers an area of 13.95 ha (Table I). Based on the count made in the six plots, and since the average number of mature individuals proved to be 808/10,000 m^2, the consistence of the population was estimated to be 11,276 adult *J. turbinata* plants. As there were some more isolated individuals scattered in neighbouring plant communities, the overall population of Piano Pirrera was judged to exceed 12,000 individuals and therefore is the largest known population to-date for Quaternary sand deposits in Sicily.

On the same plots, the distribution age of the individuals was studied, based on the size index and vitality classes using the method proposed by Gardner and Fischer (1996) and El-Bana et al. (2010). The size index was assumed to be an indicator of the individual's age, as it is difficult to estimate through dendrometric analysis. Contrary to this, vitality classes do not seem correlated to age, but to density. The joint evaluation of the size and vitality class diagrams (Figure 4) shows the behaviour of the juniper population in relation to the density of the individuals. A high density may be due to the abundance of young and vital individuals (plot 4), probably owing to a previous colonization or the presence of a large number of median aged individuals leading to a high percentage of suffering individuals (plot 1); a few large individuals and open space favours regeneration, low competition and high vitality (plot 3), while intermediate density generally leads to good vitality and low regeneration (plots 2, 5 and 6).

Table I. Some variables of *Juniperus turbinata* population of Piano Pirrera.

Juniperus turbinata Piano Pirrera	Plot 1			Plot 2			Plot 3			Plot 4			Plot 5			Plot 6			Total area 13.95 ha
No. of Individuals/ 200mq	22			11			8			26			13			17			11,276
	Mean value	Max value	Min value	Mean value	Max value	Min value	Mean value	Max value	Min value	Mean value	Max value	Min value	Mean value	Max value	Min value	Mean value	Max value	Min value	Mean value
Density (ind/ha)	1100			550			400			1300			650			850			808.33
Height (H) (m/ind)	3.9	5.5	1.9	3.1	5.5	0.9	3.9	6.5	2.2	2.6	3.8	1.3	3.8	5	2.5	3	4.4	1.4	
Crown diameter (D) (m/ind)	2.4	5.6	1	2.6	5.5	0.5	3.6	8	0.8	2	5.3	0.6	3.7	5.9	2	3.1	5.2	3	
Size index [(H + D)/2] (m/ind)	3.2	5.1	1.7	2.8	0.7	5.1	3.7	7.2	1.5	2.3	5.1	1	3.8	5.2	2.3	3.1	4.5	1.6	
Height/crown diameter H/D	1.58			1.19			1.08			1.3			1.02			0.96			

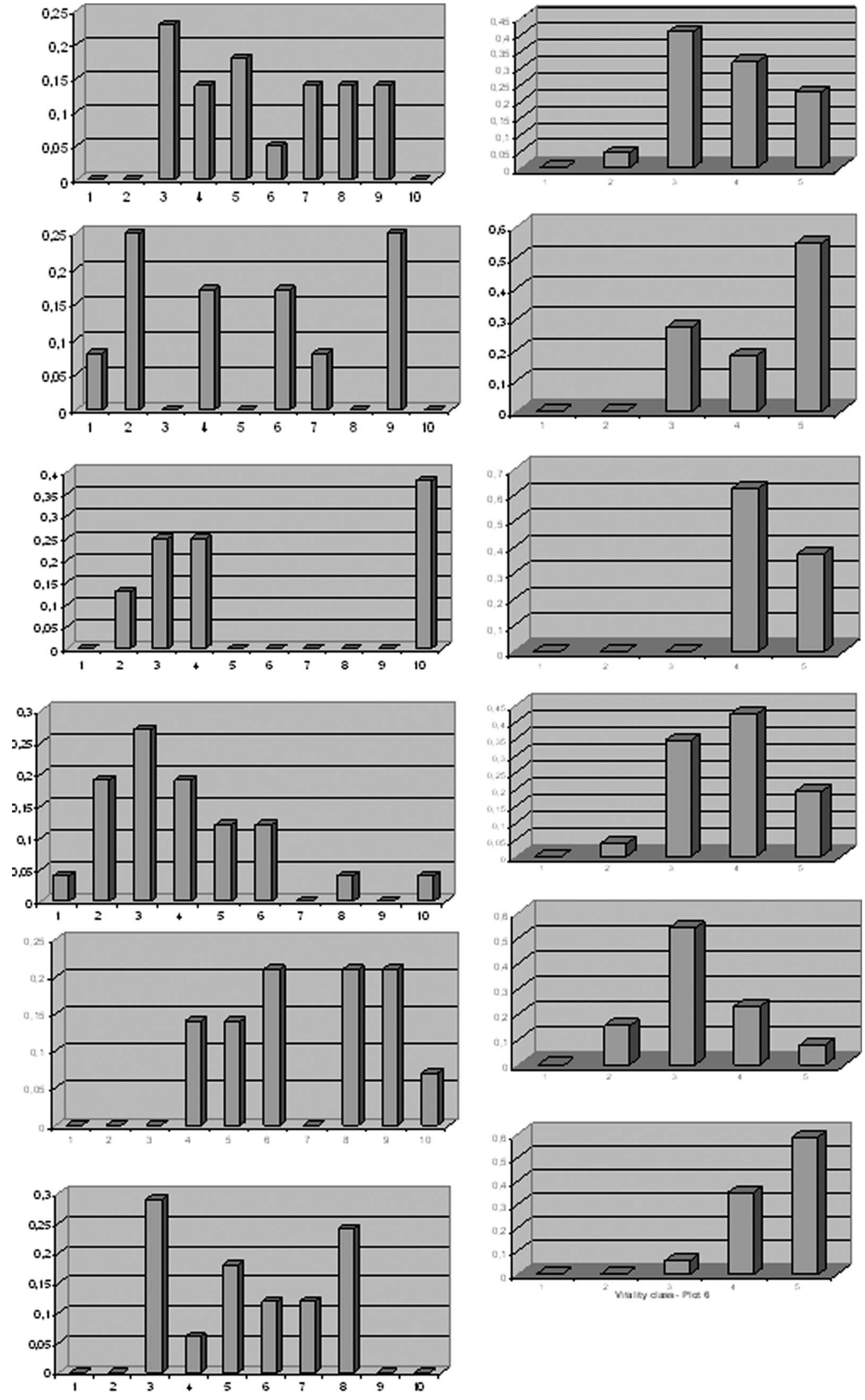

Figure 4. Size index –frequency distribution (on the left), and vitality class (on the right) of the *Juniperus turbinata* population of Piano Pirrera (six plots – n.1 on the top, n.6 on the bottom). The ranges of size classes (from El-Bana et al. 2010 modified), are as follows: 1 = <1, 2 = 1.0–1.5, 3 = 1.5–2, 4 = 2–2.5, 5 = 2.5–3, 6 = 3.0–3.5, 7 = 3.5–4.0, 8 = 4.0–4.5, 9 = 4.5–5.0 and 10 = >5.0 m). The ranges of vitality classes are as follows: 1 = 0–20% of branches supporting living biomass, 2 = 21–40%, 3 = 41–60%, 4 = 61–80%, 5 = 81–100%.

If we compare mean, minimum and maximum size index of each plot (Figure 5), the higher size indices are favoured with a low density; note that the maximum value almost always falls within the tenth class. On the other hand, high density favours individuals with a high H/D ratio and slender shape (Figure 6). The data analysis showed an overall marked prevalence of old individuals, with a subordinate presence of younger individuals.

Juniperus turbinata *community*

From a phytosociological viewpoint, the reference community of the juniper-vegetation in south-

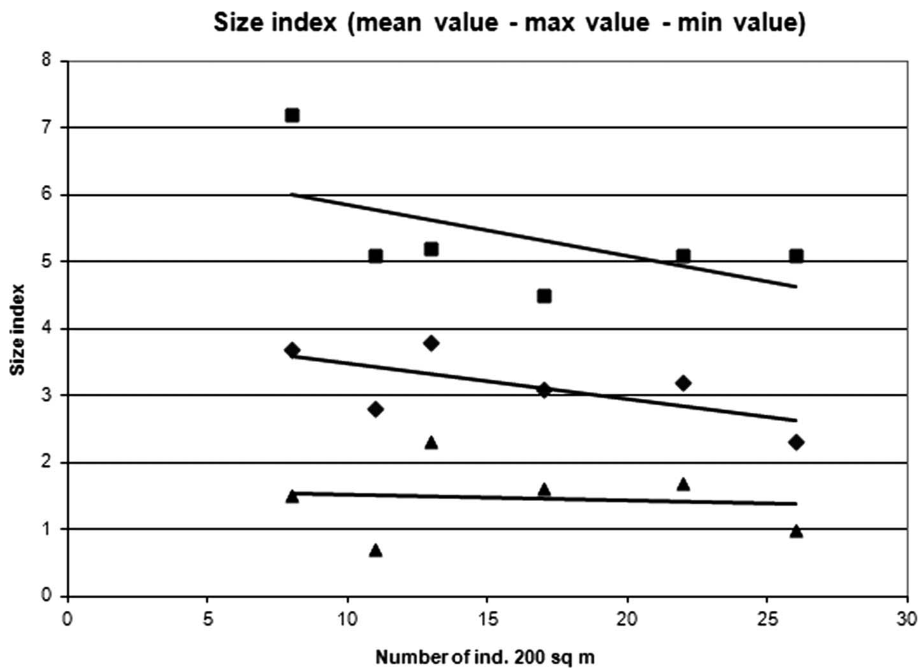

Figure 5. Size index correlated with number of individuals.

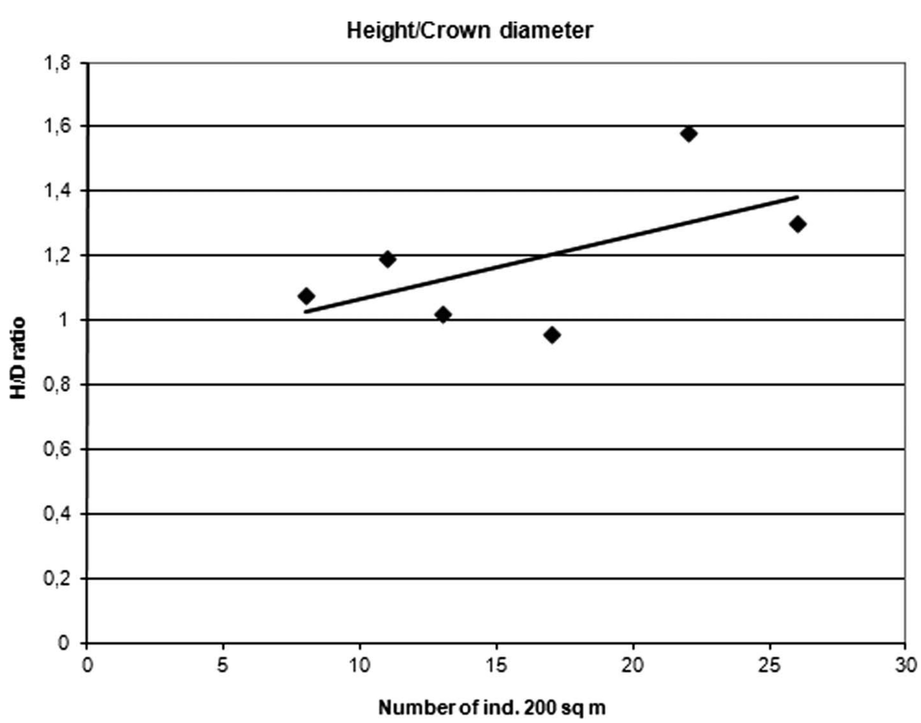

Figure 6. H/D ratio correlated with number of individuals.

eastern Sicily is *Junipero turbinatae-Quercetum calliprini* (Bartolo et al. 1982; Brullo et al. 2008). In our stands, despite the remarkably similar floristic settlement, *Quercus calliprinos* is missing, probably due to the extremely dry environmental conditions. Indeed, it normally grows together with juniper on sandy soils but may require a little more humid edaphic conditions. Therefore, the phytosociological frame of the stand investigated was reconsidered and compared to the other known stands on sandy soils in south-eastern Sicily (Appendix I) based on the cluster analysis of 46 relevés (Table II), in order to highlight the ecological gradients which determine the differentiation of plant communities (Čarni et al. 2011). The result of the cluster analysis (Figure 7) shows two main vegetation groups. Group A contains the plant communities belonging to the *Juniperion turbinatae* alliance, while Group B contains the communities belonging to the *Oleo-Ceratonion* alliance. Two subgroups are distinguished in Group A: the first one (A1, 21 relevés) represents the inland community on the sunny slope of Piano Pirrera, and the second one (A2, 11 relevés) is the typical *Junipero turbinatae-Quercetum calliprini* community of the consolidated dunes, not far from the sea. Group B (14 relevés) represents inland communities of the north slopes. Two subgroups can also be distinguished here, the first one (B1, 7 relevés) is characterized by *J. turbinata* and the second one (B2, 7 relevés) by *Quercus calliprinos*. All these groups have a different ecological significance, in particular regarding microclimate, anthropic disturbance and position in vegetation series.

These observations are better explained by CCA applied to the same 46 relevès. The main matrix considers 46 plots and 57 species. The second matrix correlates the plots with five variables: distance from the sea, aspect, slope, altitude and the type of sandy soils [type 1 (txc), type 2 (lri)]. CCA (Figure 8) shows a mass of points corresponding to the plots (triangle) and other scattered points corresponding to the species (+). The two axes outline two

Table II. Relevés of *Juniperus turbinata* communities analysed in Sicily.

Locality	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Relevé number (orig.)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	1	2	3	4	5	6	7	1	2	1	2	3	4	6	7	8	9	10	11	12	14	15	16	1	2
Surface (mq)	200	100	100	100	100	100	100	100	200	100	100	200	200	100	100	100	100	100	100	200	200	100	50	100	100	80	100	95	100	100	100	100	100	50	100	40	80	50	100	100	100	80	100	100	50	50
Coverage(%)	80	100	100	100	100	100	100	100	90	90	95	70	95	95	90	90	95	90	95	100	100	100	100	100	100	80	100	95	100	100	70	90	90	80	80	70	90	100	90	100	100	90	100	100	100	100
Aspect	S	NO	S	S	S	SE	SE	SE	S	SE	SE	E	SE	SE	SE	SE	SE	S	S	SE	S	O	O	O	O	O	O	O	E	E	N	N	NE	N	N	N	O	O	O	O	O	N	N	N	NE	NE
Slope °	20	30	25	25	25	15	25	30	5	15	15	15	20	25	25	30	25	50	40	10	25	5	5	5	5	5	5	5	5	5	30	20	40	20	15	20	15	10	15	15	20	10	15	15	30	30
Soil	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	txc	txc	txc	txc	txc	txc	txc	txc	txc	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri	lri
Altitude (m)	145	107	127	128	128	130	126	125	140	130	122	113	114	131	135	135	140	140	135	140	135	30	30	30	30	30	30	30	30	30	88	93	94	90	94	94	120	120	130	130	120	125	130	130	70	80
Distance of sea (m)	8500	8200	8450	8450	8450	8450	8450	8450	8500	8400	8400	8500	8300	8300	9500	9500	9400	9400	9100	8950	9000	1300	1300	1300	1300	1300	1300	1300	1300	1300	6500	6500	6500	6500	6500	6500	8400	8400	8400	8400	8400	8500	8500	8500	5250	5250
N. species	47	53	47	47	46	48	52	53	46	50	49	38	50	45	45	45	45	46	50	44	44	50	45	43	44	48	46	45	48	46	47	45	46	47	52	48	47	42	47	47	51	47	50	52	48	50
Characteristic of alliance																																														
S1 *Juniperus turbinata Guss.*	2	1	2	4	3	5	4	4	5	4	4	4	4	4	5	1	+	2	4	5	5	4	4	4	3	3	4	4	3	3	2	1	3	1	3	2	1	.	.	.	.	.	.	.	1	1
S2 *Quercus calliprinos Webb*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	+	2	2	+	2	1	2	+	.	.	.	1	1	.	4	2	1	2	3	4	4	3	3
S3 *Pistacia lentiscus L.*	3	4	4	3	3	1	3	4	2	2	4	2	1	2	3	3	2	3	3	3	3	2	3	2	2	.	2	2	2	1	3	1	2	1	3	3	2	2	2	2	4	2	3	3	3	2
S4 *Phillyrea latifolia L.*	.	.	1	+	1	+	1	+	1	2	1	1	1	1	1	1	+	+	1	1	1	2	2	1	1	2	1	2	1	1	1	1	2	1	3	2	4	.	2	1	2	1	1	2	3	3
S5 *Teucrium fruticans L.*	.	1	1	1	2	1	1	1	1	+	1	.	+	1	1	1	+	+	1	1	1	+	1	1	+	+	1	1	1	1	2	2	1	2	.	.	2	1	1	1	2	2	2	2	1	2
S6 *Olea europaea L. var. sylvestris (Mill.) Lehr*	2	2	1	2	2	1	2	2	1	1	1	1	1	1	2	2	2	2	1	2	1	1	.	+	.	+	+	.	1	1	+	+	1	1	1	+	1	.	.	.	1	1	1	1	2	1
S7 *Calicotome infesta (C. Presl in J. & C. Presl) Guss.*	3	3	1	1	2	+	+	1	1	1	1	.	1	+	1	.	.	.	+	.	.	+	.	.	2	+	+	1	+	.	2	3	2	3	1	1	3	.	1	2	+	1	+	1	2	2
S8 *Ephedra fragilis Desf.*	2	2	3	2	1	2	2	1	+	1	2	.	1	1	1	+	+	1	1	1	+	1	1	1	.	+	1	1	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2
S9 *Ceratonia siliqua L.*	.	.	1	1	1	1	+	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+	.	+	+	.	.	1	+	1	.	.	.	.	.
S10 *Chamaerops humilis L.*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	.	.	.	1	+	+	+	+	.	+	1	+	.	.	.	.	.	.	.	1	.	.	.	.	1	+	+	.
S11 *Rhamnus alaternus L.*	.	1	2	2	2	1	1	2	.	.	.	.	1	.	.	.	.	.	.	.	.	.	+	+	.	+	+	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2
S12 *Asparagus albus L.*	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
S13 *Juniperus oxycedrus L. subsp. macrocarpa (Sm.) Ball*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	+
S14 *Clematis cirrhosa L.*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Characteristic of class																																														
S15 *Asparagus acutifolius L.*	2	1	+	+	+	+	+	+	1	+	+	.	+	+	+	.	.	+	+	+	+	1	+	1	+	1	1	1	+	1	1	1	+	1	1	1	2	2	1	1	2	1	1	1	.	.
S16 *Prasium majus L.*	1	1	+	1	1	+	2	1	.	+	1	.	+	+	+	.	.	.	+	.	.	+	+	1	+	1	1	1	1	+	.	1	+	+	1	+	2	2	1	1	2	1	1	1	1	1
S17 *Arisarum vulgare Targ.-Tozz.*	2	+	+	+	+	+	1	1	1	+	+	.	+	.	+	.	.	+	+	+	.	.	+	+	.	+	+	+	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.
S18 *Euphorbia dendroides L.*	.	.	2	3	1	2	2	2	+	1	1	.	1	.	2	4	4	3	1	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
S19 *Quercus suber L.*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	3	1	+	1	1	1	3	2	1	4	1	+	1	.	.
S20 *Rubia peregrina L.*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	+	+	.	.	+	.	+	.	1	1	.	1	.	.	1	1	1	2	.	.
S21 *Smilax aspera L.*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	+	.	3	.	+	+	.	.	.	.	.	.	.	.	.	.	1	2	1	2	+	1
S22 *Daphne gnidium L.*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	+	.	1	1	.	.	1	.	1	.	.	1	.	.
S23 *Quercus ilex L.*	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	+	.	.	.	.	+	2	1	2	.	.	.	.	.	.	.	.	.	.	.	1
S24 *Lonicera implexa Aiton*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	1	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+
S25 *Teucrium flavum L.*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	2	.	.	.	1	.	.	1	.	1
S26 *Arbutus unedo L.*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.	.
S27 *Euphorbia characias L.*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
S28 *Tamus communis L.*	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Other species																																														
S29 *Rosmarinus officinalis L.*	1	1	2	1	1	2	2	3	2	3	2	2	3	3	1	2	3	3	3	2	1	1	.	.	1	1	.	+	1	.	.	.	.	.	.	.	+	.	2	3	1	.	.	.	1	2
S30 *Dactylis glomerata L. subsp. hispanica (Roth) Nyman*	.	.	.	.	+	.	+	+	.	1	+	+	+	+	+	.	.	.	+	+	+	+	+	+	.	.	+	+	.	.	+	+	+	+	.	.	.	+	1	1	1	1	1	1	.	.
S31 *Cistus creticus L.*	.	2	+	+	.	+	+	+	2	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	+	1	.	2	2	2	2	1	1	+	2	3	2	1	1	+	.	.
S32 *Ampelodesmos mauritanicus (Poir.) T. Durand & Schinz*	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	1	+	1	+	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	2	2	1	+	1	2	+	1	1	+	+	1
S33 *Asphodelus ramosus L.*	+	+	+	.	.	+	+	+	+	+	+	.	+	+	.	+	+	+	+	+	+	+	+	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
S34 *Piptatherum caerulescens (Desf.) P. Beauv.*	+	+	1	+	1	1	1	1	1	+	1	.	+	+	1	+	+	+	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
S35 *Charybdis pancration (Steinh.) Speta*	+	+	.	+	.	.	.	.	+	+	.	+	+	.	+	+	+	+	+	+	+	+	.	.	+	+	.	+	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
S36 *Micromeria graeca (L.) Benth. ex Rchb.*	1	+	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	+	1	2	1	1	1	1	1	1	1	+	+	.	.
S37 *Phagnalon saxatile (L.) Cass.*	1	+	+	+	+	.	.	+	+	+	+	.	+	+	.	.	.	.	+	.	+	.	.	.	.	.	.	.	+	.	.	.	.	1	+	.	1	.	.	.	.	.	+	+	.	.
S38 *Teucrium capitatum L.*	.	.	.	.	.	.	+	+	+	+	+	.	+	+	+	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
S39 *Helianthemum lippii (L.) Dum.-Cours.*	1	.	.	.	.	+	+	+	.	+	+	.	+	+	+	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
S40 *Convolvulus althaeoides L.*	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	+	.	+	+	+	.	.
S41 *Cistus monspeliensis L.*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	2	.	.	1	.	.	.	.	.	1	+	.	.
S42 *Piptatherum miliaceum (L.) Coss.*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
S43 *Cistus salvifolius L.*	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	1	1	.	.	.	.	.	.	.	.	1	2
S44 *Phagnalon rupestre (L.) DC.*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	1	1	.	.	.	.	.	1	+	+	.	.
S45 *Salsola oppositifolia Desf.*	1	.	1	+	+	.	.	.	.	.	.	.	.	.	.	1	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
S46 *Coridothymus capitatus (L.) Rchb.*	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	1	2	+	.	.	.	.	.
S47 *Bituminaria bituminosa (L.) E. H. Stirton*	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	+	1	1	.	.	.	.	.
S48 *Ononis hispanica L. subsp. ramosissima (Desf.) Förther & Pod*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	+	+	.	.	.	.	.	+	+	.	.	.
S49 *Thapsia garganica L.*	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
S50 *Erica multiflora L.*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	2	1	1	.	.	.	1	1
S51 *Acanthus mollis L.*	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	.	.
S52 *Hyparrhenia hirta (L.) Stapf*	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
S53 *Pinus halepensis Mill.*	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	+	.	.	.	.	.	.	.	.	.	2	1
S54 *Rumex bucephalophorus L.*	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
S55 *Cachrys pungens Jan ex Guss.*	.	.	.	.	.	+	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
S56 *Melica minuta L.*	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+
S57 *Allium subhirsutum L.*	.	1	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

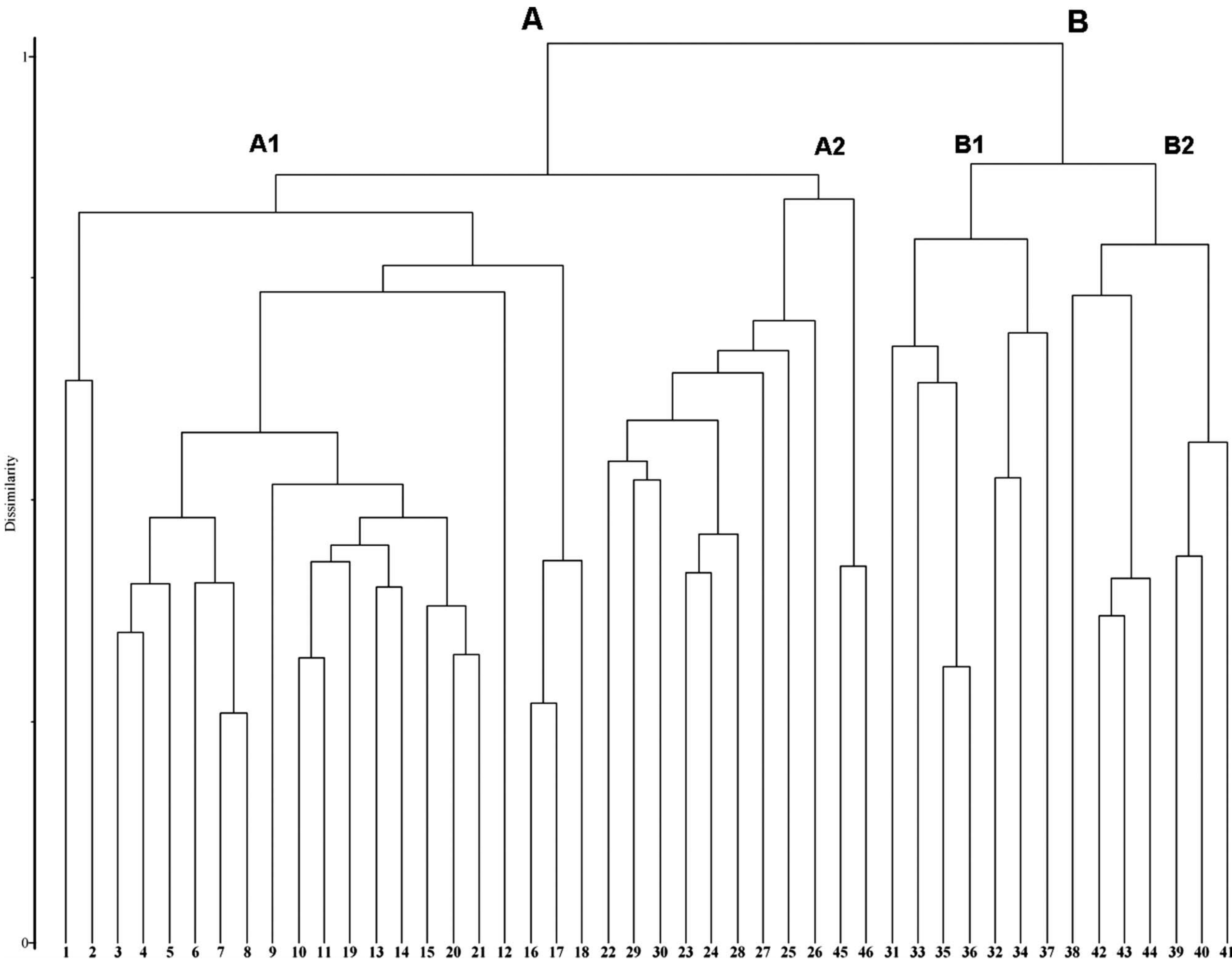

Figure 7. Cluster analysis, UPGMA method and chord coefficient.

important gradients: axis 1 can be considered a xerothermic gradient, on the right part of the axis is a cloud of points representing the community with *J. turbinata* as the unique dominant species; it is related to the south-facing slope and distance from the sea, factors which determine drier conditions. The communities on the left part of the axis are both coastal and inland, growing on north-facing slopes which determines a moderate mesicity caused by marine moisture in the first case and by cool shade in the second. Axis 2 separates the plant communities according to soil type: at the bottom is *Junipero turbinatae-Querco calliprini*, growing on xeropsamment of consolidated dunes (txc), at the top are the communities related to the Sicilian acidophilous, thermophilous series of *Stipo bromoidis-Querco suberis sigmetum* growing on lithic rhodoxeralf formed from calcarenites and incoherent deposits (lri). The series of this territory have been outlined by Bazan et al. (2010) according to the method of Blasi et al. (2000, 2005), but now this study can contribute to the identification of accessory communities. In particular, the *Juniperus* stand of south facing slopes is a more capable edaphoxerophilous community than *Quercus suber*, which colonizes (or rather had colonized before human exploitation) the plains area and northern exposed slopes. The communities of the north facing slope (group B of cluster analysis) and generally dominated by thorny oak represent stages of degradation of a cork oak forest. *Quercus calliprinos* was an important component of primary cork oak forests of which only a few degraded edges remain today (Minissale & Sciandrello 2005). Indeed, in addition to *Quercus calliprinos* and sometimes *J. turbinata*, *Cistus* sp. pl. and *Ampelodesmos mauritanicus* are also present.

Inside these communities, where juniper and thorny oak have different weights in terms of abundance dominance, CCA also aids in recognizing different groups of typical species which are useful in characterizing the communities as proposed by Biondi (2011). Group A2 of cluster analysis, *Junipero turbinatae-Quercetum calliprini*, is characterized by *Chamaerops humilis*, a species having its optimum on the maquis of rocky coasts but here it highlights the stability of the sandy substrate. Group A1 of

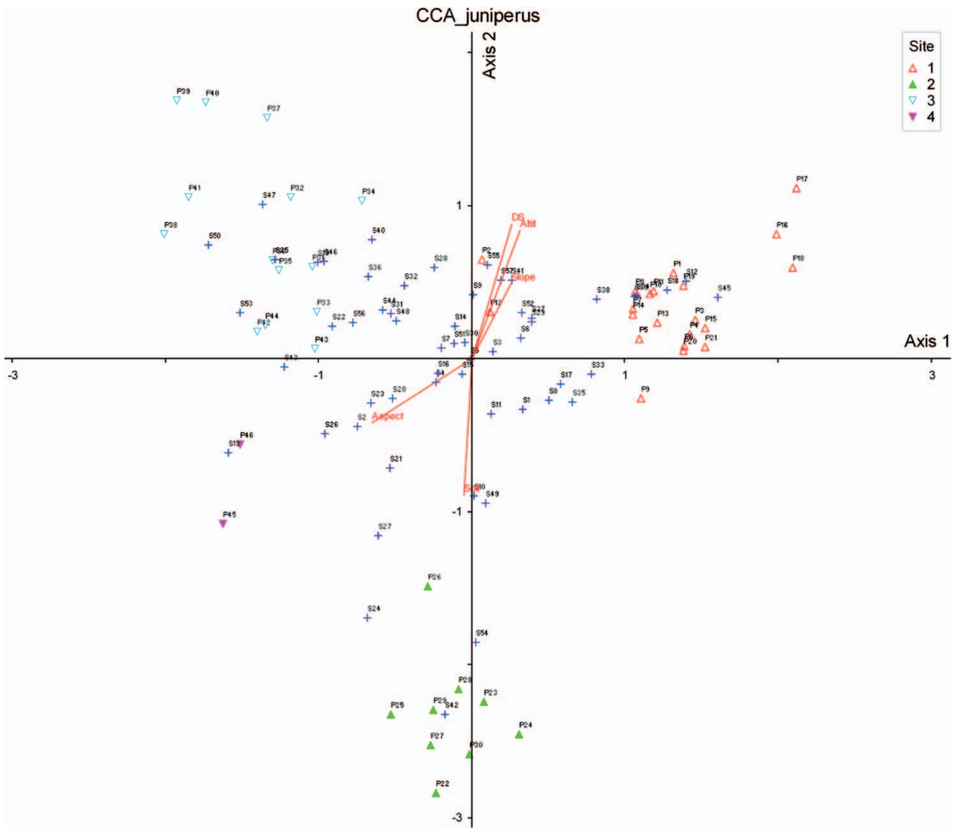

Figure 8. Ordination. Total variance (inertia) in the species data: 1.7301. Eigen value: Axis 1, 0.249; Axis 2, 0.147. Variance in species data % of variance explained: Axis 1, 14.4; Axis 2, 8.5; Cumulative % explained: Axis 1, 14.4; Axis 2, 22.9. Pearson Correlation, Spp-Envt*: Axis 1, 0.902; axis 2, 0.921.*Correlation between sample scores for an axis derived from the species data and the sample scores that are linear combinations of the environmental variables. Site 1, Piano Pirrera; 2, Passo Marinaro; 3, Piano Stella; 4, Valle Ippari.

cluster analysis proposes, as a new association (Holotypus: Table II, rel. 2), the name *Piptathero caerulescentis-Juniperetum turbinatae* which is differentiated by *Piptatherum caerulescens*, *Rosmarinus officinalis* and *Euphorbia dendroides*, showing edaphoxerophilous conditions. Group B (cluster analysis) represents a degradation stage of the cork oak woodlands, characterized by *Cistus creticus*, *Ampelodesmos mauritanicus*, *Micromeria graeca* and lastly *Quercus suber* that highlights its serial link. For this community, as a new association, the name *Calicotomo infestae-Quercetum calliprini* is proposed (Holotypus: Table II, rel. 44). Within this community, two new subassociations can be distinguished, the first one (B2) *typicum*, where *Q. calliprinos* is dominant, and the second (B1) *juniperetosum turbinatae* (Holotypus: Table II, rel. 35), where *J. turbinata* is present because tree and shrub coverage is less dense (see syntaxonomic scheme in Appendix II).

Discussion and conclusion

Several authors have highlighted the pioneering ability of *Juniperus phoenicea* s.l. especially in sandy environments (Quezel & Medail 2003; Petit et al. 2005; Boratynski et al. 2009). Indeed, this species colonizes hostile environments characterized by edaphic and climatic aridity. It is interesting to note that *J. turbinata*, in its native range, grows in both sandy and rocky habitats (Asensi et al. 2007) both quite hostile but different from each other. Therefore, it is worth asking whether this species exists in different ecotypes that are recognizable even at a morphological level. Mazur et al. (2010) highlighted the significant morphological variability within *J. turbinata* in the western Mediterranean. This variability is not related to the different habitats, but rather the isolation of populations in different areas of refuge during the Quaternary glaciations. It should be noted that the major morphological differences were found in the sole Italian population investigated (Capo Rizzuto). Even at the genetic level, significant differences have been reported in different populations (Boratynski et al. 2009). A close examination of our samples collected in Cilento (South Italy) and Croatia, both rocky habitats, shows morphological differences from the southern Sicily samples, especially in galbulus size (larger in Sicily) and number of seeds (6–7 in the Sicilian populations, 7–9 in the other). It would therefore be necessary to carry out targeted surveys of different populations to see if there is any correlation between morphology and habitat, but also to better define the distribution of *J. turbinata* and *J. phoenicea* in the Mediterranean.

The study of a representative community like that of Piano Pirrera has provided an indication of its dynamic population and conservation status.

Comparison of our population with another Juniper stand reported from Egypt (El-Bana et al. 2010) has shown a higher density of individuals per hectare in the Sicilian population of a magnitude order of about 10 times greater; this may be related not only to the regression of the Egyptian populations due to climate change and anthropogenic impact but also to rocky soil associated. Size index of the two populations is, however, of the same order of magnitude.

Concerning regeneration processes, our population shows that once individuals have established themselves and remain in situ for hundreds of years, the regeneration is somewhat limited. It should also be considered that renovation is also reduced because of the considerably xeric environment, hampering the vitality of seedlings on bare soil. New seedlings thrive in the undergrowth among low shrubs such as *Pistacia lentiscus*, *Rosmarinus officinalis* or the same *Juniperus turbinata*, which acts like a nursery. Shade may be another factor responsible for enhanced seedling survival under shrubs. In these hot and arid environments, plants growing in open areas are subject to potentially lethal soil temperatures and intense water loss by transpiration and evaporation (Shumway 2000; Flores & Jurado 2003, Armas & Pugnaire 2009), but the seedlings may reach adult age only in cases of occasional thinning-out of the sheltering shrubs. However, this research shows that juniper is characterized by population dynamics with a low turnover. This is typical of some trees of climax communities, but in juniper such a characteristic is heightened because new seedlings are very rare even in a population of thousands of individuals, producing millions of seeds, such as Piano Pirrera. Therefore, the old but very tested concept of K strategist (Gadgil & Solbrig 1972) fits well to *J. turbinata*.

Vegetation analysis highlights the role of *J. turbinata* in Sicilian sandy woody communities and its ecological differences with *Quercus calliprinos*. Although the latter species is listed as the most thermophilous oak of Sicily (Pasta et al. 2000) compared to juniper, it shows a more mesic character in that in inland territories it needs edaphic freshness which it can find on north-facing slopes or in the underwood of cork oak forest. Along the coast, a weak microclimatic freshness is given by hidden precipitation although, in the community, this species is not dominant. Unfortunately, the exploitation of consolidated coastal dunes in Sicily does not allow a wider comparison of communities referable to *Junipero turbinatae-Quercetum calliprini* to be made. *Juniperus turbinata*, however, shows its capacity to resist edaphic and climatic aridity; it is dominant along the coast and on south-facing slopes where it becomes the only species of the arboreal layer. Its presence in *Calicotomo infestae-Quercetum calliprini* is not constant as it needs good lighting and this condition occurs only if the arboreal layer is not too thick.

The defining of sigmeta may be better understood at a landscape scale as discussed by Blasi et al. (2005) in order to recognize different geosigmeta and in particular "topographic or geomorphologic" geosigmeta (Rivas-Martínez 2005). In this sense, it is possible to separate two landscape units: dune environment and inland sandy hills. *Ephedro Juniperetum macrocarpae/Junipero Quercetum calliprini* geosigmetum may be referred to the first unit (G1). The second one on sandy hills is characterized by *Stipo bromoidi Quercetum suberis/ Piptathero-Juniperetum turbinatae* geosigmetum (G2); *Quercus ilex* wood (*Pistacio lentisci-Quercetum ilicis* Brullo & Marcenò 1985), which is present on steeper north-facing slopes and often inside watersheds on inland sandy hills further from the sea such as Santo Pietro (Furnari 1965), is also involved in this geosigmetum.

Catenal contact of these geosigmeta is outlined in Figure 9 by two transects of vegetation: the first one is the potential vegetation with no or very limited human disturbance; the second is the actual situation with a brief identification of the communities of substitution. Reconstruction of the vegetation arrangement concurs with the conclusion of Noti et al. (2009) concerning vegetation of the last millennia around the nearby site of Biviere di Gela using pollen deposits. However, we have now improved and clarified the environmental framework with respect to the small but significant changes in ecological conditions to which the vegetation has adapted and responds as an indicator (Poldini et al. 2011).

All these considerations highlight the need for serious conservation actions to guarantee the survival of the residual populations of *J. turbinata* communities in south-eastern Sicily. The previously known populations are included in the SCI of Natura 2000 European network, in regional natural reserves (Pineta di Vittoria) or archaeological sites (Passo Marinaro), but they are surrounded by areas which have been altered by human activity such as intensive agriculture. The conservation-polls of the new Piano Pirrera site are fairly positive as it falls within the state property managed by the Regional Forestry Agency. The only real risks for these populations are wild fires and forest planting with *Pinus halepensis*, but such actions are to-date very limited or controlled. On the basis of this survey, it has recently been proposed to expand the nearby Natura 2000 site ITA050001

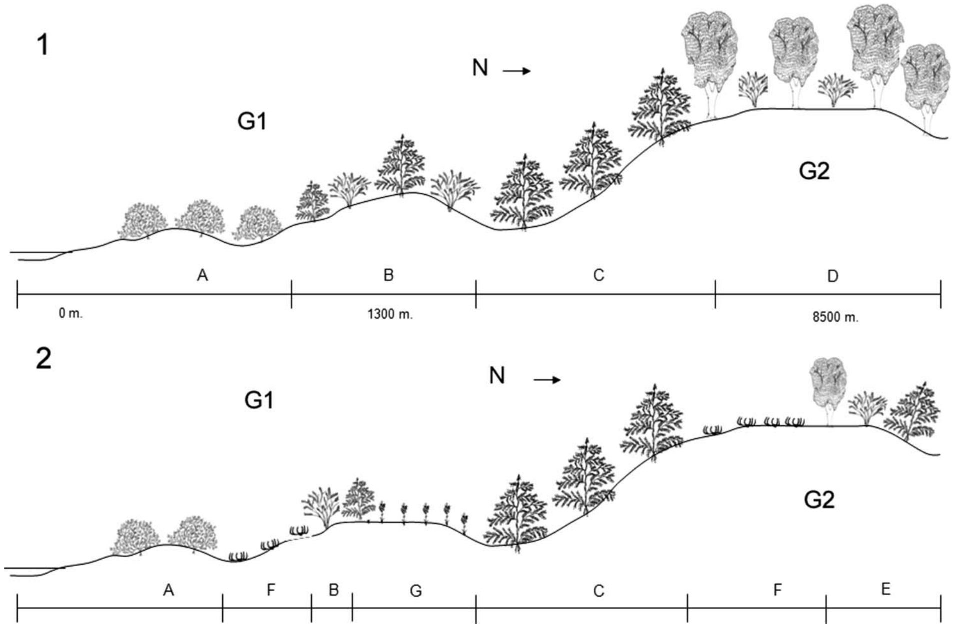

Figure 9. Transects of the geosigmeta of the Gulf of Gela: potential vegetation (1) and real vegetation (2) in the best areas. On the left, the dune environment (G1) and on the right, the inland sandy hills (G2). A. *Ephedro-Juniperetum macrocarpae*; B. *Junipero-Quercetum calliprini*; C. *Piptathero caerulescentis-Juniperetum turbinatae*; D. *Stipo bromoidis-Quercetum suberis*; E. *Calicotomo-Quercetum calliprini*; F. *Malcolmietalia* community; G. *Stellarietea mediae* (cultivated lands). The interposed alluvial plain areas are omitted.

''Biviere e Macconi di Gela'', in order to include this extraordinary example of the priority habitat 2250* ''Coastal dunes with *Juniperus* spp.''. Our preference is 2250 instead of 5210 ''Matorral of *Juniperus* spp.'' because the population grows on sands of Pleistocene about 8 km from the sea whereas 5210 should be used for the populations growing on rocky habitats.

Juniperus turbinata is included in the Italian regional red list (Conti et al. 1997) for Sicily as VU (Vulnerable). Now, with the discovery of the large population of Piano Pirrera, this study proposes changing the risk category to NT (near threatened). As a part of a research project on indigenous germplasm of the Gela territory, funded by ENI (National Hydrocarbons Authority), activities are in progress for ex situ breeding and reintroduction in other suitable areas in the surrounding territory.

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Appendix I

Localities and data of relevés

Rel. 1–2, Piano Pirrera (Acate), 05.04.2011; Rel. 3–8, Piano Pirrera (Acate), 21.10.2010; Rel. 9, Piano Pirrera (Acate), 05.04.2011; Rel. 10–14, Piano Pirrera (Acate), 10.05.2011; Rel. 15–21, Piano Pirrera (Acate), 27.05.2011; Rel. 22–28 Passo Marinaro (Scoglitti), (from Bartolo et al. 1982);

Rel. 29–30, Passo Marinaro (Scoglitti) (from Brullo et al. 2010, Tab.2a); Rel. 31–44, Piano Stella (from Minissale & Sciandrello 2005, Tab. 4); Rel. 45–46, Valle dell'Ippari (from Brullo et al. 1993, Tab.3).

Appendix II

Syntaxonomic scheme

QUERCETEA ILICIS Br.-Bl. ex A. & O. Bolòs 1950
QUERCETALIA CALLIPRINI Zohary 1955
JUNIPERION TURBINATAE Rivas-Martínez 1975 corr. Rivas-Martínez 1987
Junipero turbinatae-Quercetum calliprini Bartolo, Brullo & Marcenò 1982
Piptathero caerulescentis-Juniperetum turbinatae ass. nova
OLEO SYLVESTRIS-CERATONION SILIQUAE Br.-Bl. ex Guinochet e Drouineau 1944 em. Rivas-Martinez 1975
Calicotomo infestae-Quercetum calliprini ass. nova
Calicotomo infestae-Quercetum calliprini typicum subass. nova
Calicotomo infestae-Quercetum calliprini juniperetosum turbinatae subass. nova