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## Contribution to the vascular flora of Chalki Island (East Aegean, Greece) and biomonitoring of a local endemic taxon

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**Abstract:** The island of Chalki, located W of Rhodos, belongs to the East Aegean Islands and is situated at the E part of the South Aegean Island Arc. The flora of Chalki consists of 519 vascular plant taxa, 29 of which are under statutory protection, 22 are Greek endemics and 109 are reported here for the first time. We show that Chalki has the second highest percentage of Greek endemics in the phytogeographical region of the East Aegean Islands. The known distribution of *Limonium ocymifolium*, *L. sitiacum* and *Phoenix theophrasti* is expanded, being reported for the first time for the phytogeographical region of the East Aegean Islands. Finally, we assess for the first time the conservation status of *Allium chalkii*, a single-island endemic, by biomonitoring its populations.

**Key words:** *Allium chalkii*, *Limonium ocymifolium*, *Limonium sitiacum*, *Phoenix theophrasti*, island plant diversity, biomonitoring, land-bridge islands, Chalki, Aegean, Greece

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### Introduction

With more than 7000 islands and islets (Triantis & Mylonas 2009), the Aegean archipelago is one of the largest archipelagos in the world, after the Caribbean, Indonesia and the South Pacific (Blondel & al. 2010). The Aegean has long served as a meeting ground for species of varying origin, since it lies at the crossroads of three continents, namely Europe, Asia and Africa (Poulakakis & al. 2014). Its high environmental and topographical heterogeneity (Blondel & al. 2010), complex geological and palaeogeographical history, as well as its high diversity and endemism (Strid 1996) render it as an ideal stage for biodiversity studies. Intensive field work has taken place

in the Aegean phytogeographical regions of Greece, and numerous biodiversity and biogeographical studies have been carried out in recent years (e.g. Livaniou-Tiniakou & al. 2003; Kallimanis & al. 2010; Kagiampaki & al. 2011; Raus 2012; Trigas & al. 2013; Kougioumoutzis & al. 2014a) and more specifically in the phytogeographical region of the East Aegean Islands (e.g. Panitsa & al. 2006, 2010; Constantinidis 2013), which has been characterized as one of the most floristically explored phytogeographical regions of Greece (Dimopoulos & al. 2013; Bergmeier & Strid 2014). However, certain islands have not yet been the main focal areas of floristic research, leaving our knowledge of the flora of the East Aegean islands still incomplete.

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Eighteen large islands and numerous islets comprise the phytogeographical region of the East Aegean Islands, which is the floristically richest insular phytogeographical region of Greece (Dimopoulos & al. 2013). The East Aegean Islands host 2541 taxa (Dimopoulos & al. 2013), 160 of which are Greek endemics (6.3%) and demonstrate lower than normal endemism, as expected by their size (Georghiou & Delipetrou 2010). Even though the flora of the large East Aegean islands (e.g. Papatsou 1971; Carlström 1987; Christodoulakis 1996a; Brofas & al. 2001; Panitsa & Tzanoudakis 2001, 2010; Biel 2002; Panitsa & al. 2003, 2006; Bazos 2005; Zervou & al. 2009) and islets (Panitsa 1997; Panitsa & al. 2008) is well known, the flora of the smaller East Aegean islands is rather underexplored. As a contribution to fill this gap we thoroughly investigated the flora of Chalki Island.

Chalki Island (Fig. 1) is located in the E part of the South Aegean Island Arc, an island chain connecting the coasts of SE continental Greece (Peloponnisos) with SW Asia Minor and forming the S closure of the Aegean archipelago. Chalki belongs to the archipelago of Rhodos, lying c. 9 km W of Cape Armenistis. The islands comprising the Rhodos archipelago have been isolated from the adjacent island complex of Karpathos since the late Pliocene (Böger & Dermitzakis 1987) and from the Marmaris (Datça) peninsula of Asia Minor since 800 000 b.p. (Perissoratis & Conispoliatis 2003), while Chalki has been isolated from Rhodos since the offset of the last glacial maximum (Lykousis 2009). Chalki acquired its present configuration c. 8000 b.p., when the last of Chalki's surrounding islets detached from the study area (Maroukian & al. 2004).

Chalki is part of the outer island arc of the Hellenides and belongs to the geotectonic zone of Tripoli. Despite its small size (27 km<sup>2</sup>), it is characterized by a variety of geological substrates, viz. dolines with terra rossa bodies, flysch, limestone, conglomerates, scree, alluvial deposits and secondary pumice deposits (Maroukian & al. 2004).

The study area is mainly hilly with a very intense relief (especially in the SW part of Chalki), the highest peak being Maistros hill (601 m). The coastline is c. 34 km long, hosting several precipitous, coastal cliffs and many inaccessible gravelly beaches. The hydrographical network of Chalki is rather limited, with only one seasonally active stream.

The nearest meteorological station to Chalki lies in Rhodos; according to Gouvas & Sakellariou (2011), this station and hence the study area belongs to the subhu-

mid bioclimatic zone with a warm winter and also to the Thermo-mediterranean zone.

Rechinger (1944) was the first botanist to report on plants from Chalki. Most records, however, were reported thereafter in the frame of the project *Flora of Turkey and the East Aegean Islands* (Davis 1965–1985; Davis & al. 1988; Güner & al. 2001), as well as by Carlström (1987). Information on some endemic and/or rare taxa occurring in the area is given by Strid & Tan (1997, 2002). From a phytogeographical point of view, however, the interesting flora of the island of Chalki has not yet received the attention it deserves in spite of these earlier records.

Finally, *Allium chalkii* Tzanoud. & Kollmann is confined to Chalki, and thus Chalki is the smallest island in the phytogeographical region of the East Aegean Islands that hosts at least one single-island endemic. Even though *A. chalkii* is a very rare taxon, it has never before been monitored or evaluated under IUCN criteria.

Therefore, the scope of the present study aims at thoroughly investigating (1) the flora of Chalki; (2) whether its

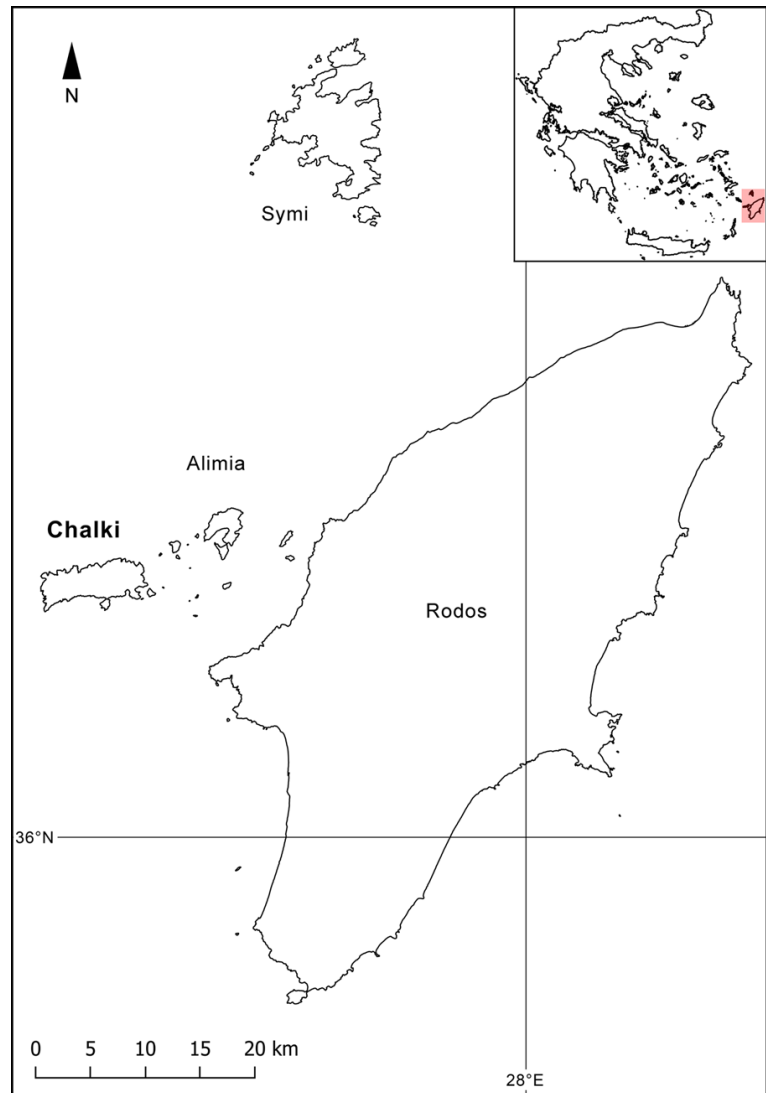


Fig. 1. Location of Chalki Island in relation to nearby islands and in the SE Aegean (inset).

flora is impoverished or not, compared to that of the other East Aegean islands; and (3) the conservation status of *Allium chalkii* with a preliminary assessment of its population size, area of occupancy and extent of occurrence.

## Material and methods

Several collection and field observation trips to the study area were carried out from April 2012 to May 2014 in order to acquire an integrated knowledge of the flora of Chalki. Herbarium specimens are deposited at the Botanical Museum of the University of Patras (UPA; herbarium code according to Thiers [continuously updated]). Species identification and nomenclature are according to Davis (1965–1985), Tutin & al. (1968–1980, 1993), Greuter & al. (1984–1989), Davis & al. (1988), Strid & Tan (1997, 2003), Güner & al. (2001), Tan & al. (2001), Greuter & Raab-Straube (2008) and Dimopoulos & al. (2013). For family delimitations we follow Dimopoulos & al. (2013). The status of the alien taxa occurring in the study area is according to Arianoutsou & al. (2010) and Dimopoulos & al. (2013). The nomenclature and status of the endemic taxa recorded from Chalki are based on Dimopoulos & al. (2013). The life-form and chorological categories follow Dimopoulos & al. (2013 – see Appendix for abbreviations used). Data regarding the endemism levels in the phytogeographical region of the East Aegean Islands are based on Panitsa & al. (2010) and Dimopoulos & al. (2013).

In order to compare the floristic diversity between islands of different size, we investigated the island species-area relationships (ISARs) for the native and endemic species occurring in the East Aegean islands (as in Panitsa & al. 2010), by fitting the logarithmic transformation of the Arrhenius (1921) power model:  $\text{Log}(S) = c + z \cdot \text{Log}(A)$ , where  $S$  is the value of each of the richness metrics used,  $A$  is the area of the respective island in  $\text{km}^2$  and  $c$ ,  $z$  the fitted parameters. A value of 1 was added to certain cases before  $\log_{10}$  transformation, because zero values were reported for some islands. Then, we used the values of the residuals from ISAR  $\log_{10}$ -transformed models of the native and endemic species occurring in the East Aegean islands, as these values are interpreted as a measure of island species diversity and do not reflect the influence of island area (Hobohm's  $\alpha$ -index; Hobohm 2000, 2003). Positive and negative values of Hobohm's  $\alpha$ -index refer to areas with species diversity above and below average, respectively (Hobohm 2000, 2003). All the diversity analyses were carried out in the R computing environment (R Core Team 2015) using core functions and functions from the ggplot2 package (Wickham 2009).

Furthermore, extensive field research has taken place in order to locate the exact locus classicus of *Allium chalkii*, and to discover possible new localities and subpopulations of this taxon in the study area. We used the Technical Guide for Mapping (Dafis & al. 2001) for the determination of the habitat types where *A. chalkii*

occurs. The terms population size, subpopulation, location, area of occupancy (AOO) and extent of occurrence (EOO) are used according to the definitions established by IUCN (IUCN Standards and Petitions Subcommittee 2010). The RAMAS Red List 3.0 software package was used for the conservation status assessment of *A. chalkii* according to the IUCN criteria (Akcakaya & Ferson 2007). All known localities of *A. chalkii* were surveyed for two consecutive years (2013–2014). Detailed mapping was performed using a GPS device and occasionally a tape measure. Polygons of the local extent of occurrence of each subpopulation were constructed. The QGIS (QGIS Development Team 2015) software package was used for data digitization and area estimations. Population size was measured by counting every individual that was at anthesis. Finally, the direct threats in the environment where *A. chalkii* occurs and the stresses they cause to its individuals were recorded and classified according to the IUCN categories (IUCN & CMP 2006).

## Results

### Flora

The vascular flora of Chalki comprises 519 taxa, belonging to 296 genera and 79 families (Table 1). Nine alien taxa are included in the plant list, but have not been considered in the floristic analysis.

The literature survey revealed 408 bibliographical reports for the study area (Rechinger 1944; Davis 1965–1986; Carlström 1987; Tzanoudakis & Kollmann 1991; Strid & Tan 1997, 2002; Cattaneo 2015). We report 109 taxa as new to Chalki (see Appendix). Twenty-two taxa are Greek endemics, four of which are new records for the study area. Eleven of the new records and 29 taxa overall are under statutory protection.

The most species-rich families in the flora of Chalki are *Asteraceae* (73 taxa), followed by *Fabaceae* (63 taxa) and *Poaceae* (47 taxa). These three families account for more than one third of the total flora (35.88%). *Caryophyllaceae* (27 taxa), *Brassicaceae* (23 taxa), *Apiaceae* (20 taxa) and *Lamiaceae* (20 taxa) are also well represented.

Among the life forms, therophytes (55.69%) dominate, followed by hemicryptophytes (18.23%), geophytes (11.18%), chamaephytes (9.21%) and phanerophytes (5.69%).

According to their general distribution, the vascular plants of Chalki can be classified into 16 main chorologi-

Table 1. Number of vascular plant taxa in the flora of Chalki Island.

Systematic unit	Families	Genera	Taxa	%
Pteridophytes	4	4	6	1.16
Gymnosperms	3	4	4	0.77
Angiosperms	72	288	509	98.07
<b>Total</b>	<b>79</b>	<b>296</b>	<b>519</b>	<b>100.00</b>

Table 2. Chorological groups in the native flora of Chalki Island.

Chorological group	Number of taxa	%	Total number of taxa	%
<b>1. Widely distributed taxa</b>			<b>92</b>	<b>18.04</b>
European	1	0.20		
European-SW Asia	50	9.80		
Euro-Siberian	5	0.98		
Paleotemperate	17	3.33		
Circumtemperate	2	0.39		
Subtropical-Tropical	6	1.18		
Cosmopolitan	11	2.16		
<b>2. Mediterranean taxa</b>			<b>388</b>	<b>76.08</b>
E Mediterranean	103	20.20		
Mediterranean	200	39.22		
Mediterranean- Atlantic	8	1.57		
Mediterranean-European	30	5.88		
Mediterranean-SW Asian	47	9.21		
<b>3. Balkan taxa</b>			<b>8</b>	<b>1.57</b>
Balkan	1	0.20		
Balkan-Italian	2	0.39		
Balkan-Anatolian	5	0.98		
<b>4. Endemic taxa</b>			<b>22</b>	<b>4.31</b>
Endemic	22	4.31		
<b>Total</b>	<b>510</b>	<b>100.00</b>	<b>510</b>	<b>100.00</b>

cal categories (Table 2). The endemic group represents 4.31 % of the total flora with 22 taxa. Phytogeographically, the endemic element is the most important group and is discussed separately. The Mediterranean chorological group predominates, highlighting the geographical position and climatic characteristics of Chalki. Within this group, the circum-Mediterranean elements are dominant, followed by the East Mediterranean taxa. The other elements are represented in lower percentages, with a relatively high portion of SW Asian elements due to the phylogeographical position of the study area.

The alien flora of Chalki comprises nine taxa (1.73 %), belonging to nine genera and nine families, all reported for the first time from Chalki. Eight of them are neophytes, and the most prominent among the invasive species are *Nicotiana glauca* Graham, *Opuntia ficus-indica* (L.) Mill. and *Oxalis pes-caprae* L., which occupy large areas.

### Endemism

The level of endemism in Chalki (4.31 %) is rather low compared to that in the whole of Greece (22.2 % – Dimopoulos & al. 2013) but, taking into consideration the small size of the study area, the short distance from the mainland, as well as the intense human pressure present on the island (i.e. high-intensity grazing, track and road construction, discarded waste materials), this percentage is rather significant. Furthermore, compared to endemism levels of those East Aegean Islands with a larger size than that of the study area (Table 3), that of Chalki is rather high, even appearing to be the second highest in the phylogeographical region of the East Aegean Islands.

The endemic species belong to 15 families and 20 genera. Families rich in endemic species in absolute numbers are *Asteraceae* and *Plumbaginaceae*, their degree of endemism (5.48 % and 75.00 %, respectively) being higher than that of the general flora (4.31 %). These results agree with the trend observed in the whole Greek endemic flora (Georghiou & Delipetrou 2010).

Among the 22 Greek endemic taxa (Table 4), there are

Table 3. Endemism in Chalki and the phylogeographical region of the East Aegean Islands, as well as in the other East Aegean islands. Data extracted from Panitsa & al. (2010) and Dimopoulos & al. (2013). The endemism percentage refers to species.

Island	%
<b>East Aegean Islands</b>	<b>6.40</b>
Ikaria	4.40
Chalki	4.31
Samos	2.92
Rhodos	2.82
Tilos	1.73
Leipsoi	1.61
Kalymnos	1.52
Symi	1.47
Chios	1.44
Telendos	1.38
Lesvos	1.08
Samiopoula	0.77
Kos	0.67
Gyali	0.54
Arkoi	0.49

Table 4. Greek endemic taxa in Chalki, their geographical distribution and their protection/conservation status.

Family	Taxon	IoI	NPI	SPI	Pe	StE	EC	NC	NE	NAe	WAe	KIK	KK	E Ae	pes
Aliaceae	<i>Allium chalkii</i> Tzanoudakis & Kollmann													*	–
Asteraceae	<i>Anthemis scopulorum</i> Rech. f.				*							*		*	–
Asteraceae	<i>Centaurea lactucifolia</i> Boiss.											*		*	RDB (VU), PD 67/81, IUCN (R)
Asteraceae	<i>Filago cretensis</i> subsp. <i>cycladium</i> Wagenitz											*		*	–
Asteraceae	<i>Scorzonera cretica</i> Willd.				*							*		*	–
Brassicaceae	<i>Fibigia lunarioides</i> (Willd.) Sweet											*		*	PD 67/81,
Campanulaceae	<i>Asyneuma giganteum</i> (Boiss.) Bormm.											*		*	RDB (VU), PD 67/81, BC, IUCN (VU)
Campanulaceae	<i>Campanula rhodensis</i> A. DC.													*	–
Caryophyllaceae	<i>Arenaria aegaea</i> Rech. f.				*							*		*	–
Caryophyllaceae	<i>Dianthus fruticosus</i> subsp. <i>rhodius</i> Runemark											*		*	PD 67/81, IUCN (R)
Chenopodiaceae	<i>Caroxylon aegaeum</i> (Rech. f.) Akhiani & Roalson				*	*						*		*	–
Crassulaceae	<i>Umbilicus albidopacus</i> Carlström													*	–
Dipsacaceae	<i>Lomelosia varifolia</i> (Boiss.) Greuter & Burdet											*		*	–
Iridaceae	<i>Crocus tournefortii</i> J. Gay				*							*		*	–
Lamiaceae	<i>Origanum calcaratum</i> Juss.											*		*	–
Orobanchaceae	<i>Odonites linkii</i> Heldr. & Sartori ex Boiss.				*	*	*	*				*		*	–
Plumbaginaceae	<i>Limonium ocymifolium</i> (Poir.) Kuntze										*			*	–
Plumbaginaceae	<i>Limonium proliferum</i> (d'Urv.) Erben & Brullo					*					*			*	–
Plumbaginaceae	<i>Limonium sitiacum</i> Rech. f.													*	–
Ranunculaceae	<i>Nigella arvensis</i> subsp. <i>brevifolia</i> Strid				*							*		*	–
Valerianaceae	<i>Valeriana asarifolia</i> Duft.				*							*		*	–
Veronicaceae	<i>Cymbalaria microcalyx</i> subsp. <i>dodekanesi</i> Greuter										*			*	–

Abbreviations: IoI = Ionian Islands; NPI = Northern Pindhos; SPI = Southern Pindhos; Pe = Peloponnisos; StE = Sterea Ellas; EC = East Central; NC = North Central; NE = North East; NAe = North Aegean Islands; WAe = West Aegean Islands; Kik = Kiklades; KK = Kriti and Karpathos; EAe = East Aegean Islands; pes = protection/conservation status; IUCN = Red List of Threatened Plants (IUCN 2010) with the following classification: population is rare (R) or vulnerable (VU); PD = Greek Presidential Decree 67/1981 on the protection of the native flora and wild fauna of Greece; BC = Bern Convention 1982.

two that obviously reflect the unique position of the study area, as it is found on the borderline of three phytogeographical regions, namely the Kiklades (Kik), the East Aegean Islands (EAe) and Kriti and Karpathos (KK): *Limonium ocymifolium* (Poir.) Kuntze and *L. sitiacum* Rech. f. These two taxa are found for the first time not only on Chalki, but in the entire phytogeographical region of the East Aegean Islands. Previously, *L. ocymifolium* was thought to be confined to Kik, while *L. sitiacum* was considered as a KK endemic.

### Range-restricted and other interesting taxa

Greece hosts 1956 range-restricted taxa (Dimopoulos & al. 2013), amounting to 29.6% of its total flora. Among the phytogeographical regions of Greece, Peloponnisos (Pe) is the richest in absolute numbers (514 taxa, 16%), while Kriti and Karpathos (KK) has the highest percentage (17.5%) of range-restricted taxa. In comparison, the phytogeographical region of the East Aegean Islands (EAe) hosts 263 (10.3%) range-restricted taxa.

All except one (*Odontites linkii* Heldr. & Sartori ex Boiss.) of the Greek endemic taxa occurring on Chalki, and 34 taxa overall (6.67%), are characterized as range restricted sensu Dimopoulos & al. (2013).

The flora of Chalki hosts 103 East Mediterranean elements, 13 of which are considered as range-restricted taxa. Chalki constitutes the southwesternmost distributional border for at least five Anatolian taxa [*Gladiolus anatolicus* (Boiss.) Stapf, *Ophrys speculum* subsp. *regisferdinandii* (Acht. & Kellerer ex Renz) Soó, *Quercus aucheri* Jaub. & Spach, *Symphytum circinale* Runemark and *Verbascum propontideum* Murb.] and the westernmost distributional border for *Campanula hagielia* Boiss., *Scorzonera elata* Boiss. and *Silene echinospermoides* Hub.-Mor.

A very interesting record is *Phoenix theophrasti* Greuter, a taxon known to occur in the Aegean region, mainly in Kriti, as well as in three areas of SW Turkey (Boydak & Barrow 1995). We believe its occurrence on Chalki to be of native origin, as its individuals were found to occupy similar ecological niches as in the Cretan locus classicus (stream banks near sea level), in two different localities. Thus, *P. theophrasti* is recorded as an indigenous member of the flora of the East Aegean Islands, whereas previous reports from Kalymnos, Kos, Nisyros and Symi have not yet been confirmed (Turland & al. 1993: 194; Thymakis 2009; Dimopoulos & al. 2013). *Phoenix theophrasti* has also been recorded from a single locality in Peloponnisos

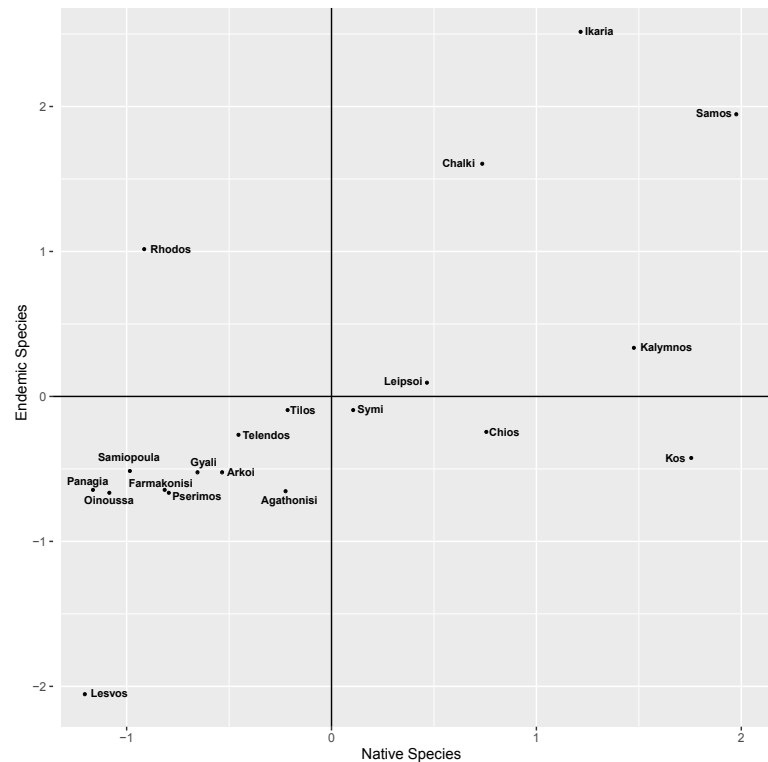


Fig. 2. Residuals scatterplot of Hobohm's  $\alpha$ -index for Greek endemic species (y-axis) versus Greek native species (x-axis), as estimated from the ISAR power function model.

Table 5. Hobohm's  $\alpha$ -index values for the total Greek native and Greek endemic species present in 20 East Aegean islands.

Island	$\alpha$ -index value native species	$\alpha$ -index value endemic species
Agathonisi	-0.22	-0.65
Arkoi	-0.53	-0.52
Chalki	0.74	1.61
Chios	0.76	-0.24
Farmakonisi	-0.81	-0.64
Gyali	-0.65	-0.52
Icaria	1.22	2.52
Kalymnos	1.48	0.34
Kos	1.76	-0.42
Leipsoi	0.47	0.10
Lesvos	-1.20	-2.05
Oinoussa	-1.08	-0.66
Panagia	-1.16	-0.64
Pserimos	-0.79	-0.66
Rhodos	-0.91	1.02
Samiopoula	-0.98	-0.51
Samos	1.98	1.95
Symi	0.11	-0.09
Telendos	-0.45	-0.26
Tilos	-0.21	-0.09



Fig. 3. *Allium chalkii* – a tuft of plants growing on a rocky, calcareous escarpment, its usual habitat. – Chalki, Lendaki, 6 May 2013, photographed by M. Tsakiri.

(Thymakis 2009) and in the phytogeographical region of the Kiklades on Milos (Kalheber in Raus 2012), Anafi (Kougioumoutzis & al. 2012) and Amorgos (Biel & Tan 2015). The presence of *P. theophrasti* on Chalki and probably other East Aegean Islands bridges the range gap between Kriti and SW Turkey.

#### Plant diversity of Chalki Island

Using Hobohm's  $\alpha$ -index (Table 5) for the Greek native and endemic species occurring in 20 East Aegean islands, Chalki presents values well above average for both of these categories (0.74 for native, 1.61 for endemic). Lesvos could be regarded as floristically impoverished, as it presents very low  $\alpha$ -values for both the native and endemic species. Chalki, Ikaria and Samos have high  $\alpha$ -values for both native and endemic species (Fig. 2), while more than half of the East Aegean islands display low  $\alpha$ -values for both species-richness metrics. Our results indicate that Chalki, Ikaria and Samos in fact constitute plant diversity hotspots, whereas islands with a large total number of native and Greek endemic species, such as Chios and Lesvos, are not characterized as such. Rhodos seems to be an endemic plant diversity hotspot in the phytogeographical region of the East Aegean Islands.

#### Preliminary assessment and conservation status of *Allium chalkii*

*Allium chalkii* is an erect, bulbous geophyte up to 8 cm tall, with membranous outer bulb tunics, bearing 2 or 3 glabrous leaves, a persistent, erect, sometimes divaricate spathe and a fastigiate, few-flowered inflorescence. The ovary is ellipsoid to oblong-ellipsoid and the capsule is globose, 3-valved, c. 3.5 mm in diam., containing black, 2–2.5 mm-long seeds. *Allium chalkii* grows in calcareous, rocky and stony crevices at 100–350 m a.s.l. and flowers from April to June (Fig. 3). Historical knowledge about this single-island endemic is scarce: *A. chalkii* was described in 1991 (Tzanoudakis & Kollmann 1991) from specimens collected in the frame of the project *Flora Hellenica* from several localities between Chorio and Kastro settlements (locus classicus) in 1986 by G. Iatrou and Th. Georgiadis and in rocky, calcareous escarpments on Chalki in 1988 by E. Karavokyrou.

*Allium chalkii* has not been evaluated before and its EOO, AOO and population size are reported here for the first time.

The current and past distribution of *Allium chalkii* is shown in Fig. 4 and Table 6. The entire population of the species consists of three subpopulations (AC1, AC2



and AC3), corresponding to the localities Lendaki, Mesovounia and Petrolakki for AC1, Agia Varvara and Kakoskali for AC2, and finally Ais Giorgis tou Riakiou for AC3. The area of the locus classicus was searched repeatedly (2012–2014) and exhaustively, but no plants were found. The fact that *A. chalkii* has not been reported from its locus classicus since 1988, suggests that this subpopulation may be extinct.

All subpopulations are scattered in seven different locations (Fig. 4, Table 6). During the two years of monitoring (2013–2014), both the EOO and the AOO – based on a 1 × 1 km grid – were estimated at 5 km<sup>2</sup>. The whole population local extent was 225 m<sup>2</sup> in 2013 and 250 m<sup>2</sup> in 2014.

Population size, expressed as the total number of mature individuals in all subpopulations, as well as the size of each subpopulation, exhibited a slight annual increase in 2014 compared to 2013 (Table 6). Total population size, local extent and the number of plants per m<sup>2</sup> (a rough estimation of plant density) were highest in 2014 in subpopulation AC1.

*Allium chalkii* occurs in stony or rocky meadows with typical Mediterranean phrygana, dominated by *Sarcopoterium spinosum* (L.) Spach and other spiny and aromatic shrubs, as well as in steep, calcareous cliffs near the sea, at 100–270 m a.s.l. *Allium chalkii* does not seem to face any imminent and direct threats, as its occurrence inside spiny phrygana and on precipitous cliffs protects it from grazing and trampling. However, habitat degradation and/or loss due to excessive grazing (stress codes 1.3 & 2.2) and road construction works (stress code 4.1), may constitute a potential threat for this species in the near future.

*Allium chalkii* is suggested to be classified as Endangered (EN), according to the IUCN (2012) criterion D, since its total population consists of fewer than 250 mature individuals.

## Discussion

The high percentages of therophytes (55.69%) and of leguminous taxa (12.35%) in Chalki indicates characteristic disturbance in Mediterranean ecosystems (Naveh 1974; Arianoutsou & Margaritis 1981; Barbero & al. 1990; Panitsa & al. 1994, 2003; Panitsa & Tzanoudakis 1998). Intense grazing and other agricultural activities have not yet ceased on Chalki and have clearly altered the island's floristic character.

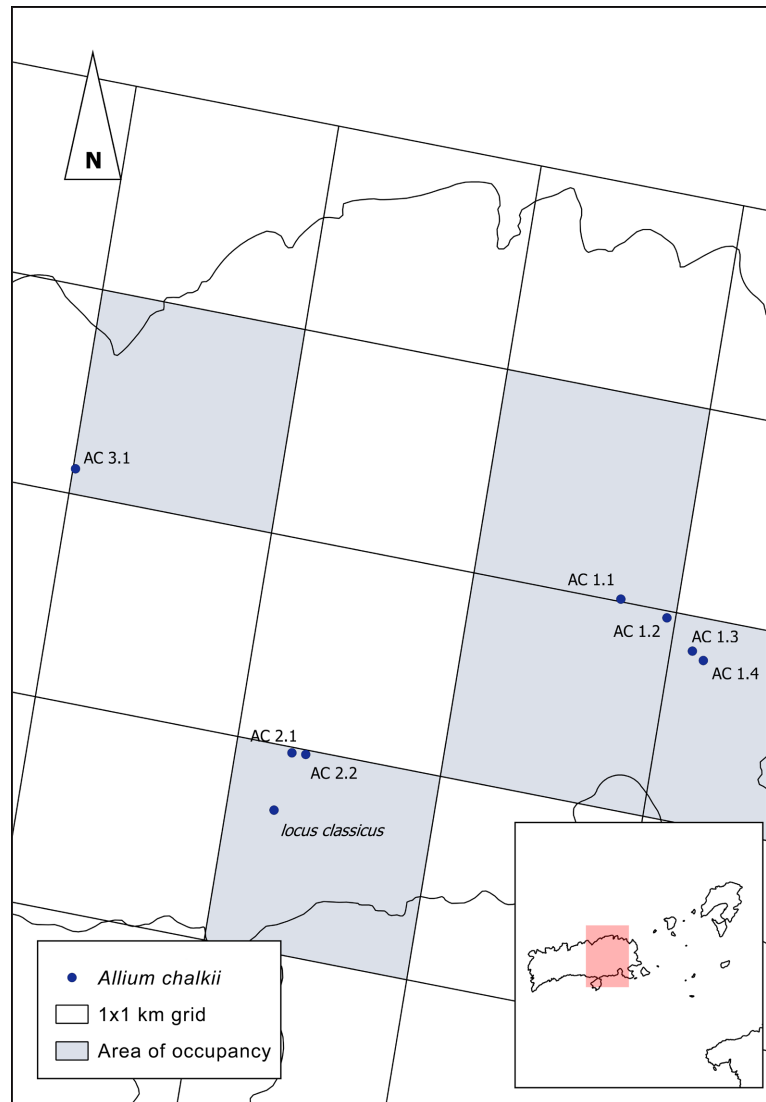


Fig. 4. Geographical distribution and area of occupancy (AOO) of *Allium chalkii*.

According to Arianoutsou & al. (2010), the total number of alien taxa accounts for c. 5% of the native flora of Greece, and this percentage is significantly higher than that of Chalki (1.54%). Nevertheless, on Chalki, where grazing grounds and abandoned farm lands occupy large areas, *Nicotiana glauca*, *Opuntia ficus-indica* and *Oxalis pes-caprae* have heavily contaminated and altered these habitats, which would otherwise be colonized by native pioneer herbs and shrubs. This phenomenon is also observed in other Aegean islands (Arianoutsou & al. 2010; Kougiumoutzis & al. 2012, 2014b, 2015).

The high percentages of chamaephytes and hemicryptophytes depend on the frequency of limestone cliffs, which very often harbour endemic taxa (Kypriotakis 1998; Kypriotakis & Tzanoudakis 2001; Tzanoudakis & al. 2006). In Chalki, the majority (63.6%) of the endemic plants are chamaephytes or hemicryptophytes, which are scattered in the numerous steep calcareous cliffs and crevices present on the island.

Table 6. Locations, subpopulations and numbers of individuals per subpopulation per year of *Allium chalkii*. – Abbreviations: SP = subpopulation; MI = mature individuals; ImI = immature individuals.

Location	SP	Colony	Altitude [m]	Aspect [°]	Slope [°]	2013		2014	
						MI	ImI	MI	ImI
Petrolakki	AC1	AC1.1	208	40	30	3	11	4	10
Mesovounia	AC1	AC1.2	166	20	10	4	9	3	8
Lendaki	AC1	AC1.3	125	170	25	4	30	3	45
Lendaki	AC1	AC1.4	103	150	20	10	12	14	11
Kakoskali	AC2	AC2.1	269	185	60	15	19	19	18
Agia Varvara	AC2	AC2.2	247	120	40	4	6	6	4
Locus classicus	AC2	AC2.3	250	–	–	–	–	–	–
Ais Giorgis tou Riakiou	AC3	AC3.1	225	100	35	4	14	6	15
<b>Total</b>						<b>44</b>	<b>101</b>	<b>55</b>	<b>111</b>

Chalki is floristically more diverse than the other parts of the phytogeographical region of the East Aegean Islands, probably because of the increased habitat diversity due to its great local topographic and geological heterogeneity (intense hilly relief with many different inclinations and exposures, and numerous geological substrates of different age), factors known to promote species richness (Whittaker & Fernández-Palacios 2007; Sfenthourakis & Triantis 2009; Panitsa & al. 2010). Its rather high level of endemism is due to its palaeogeographical history, as Chalki, contrary to the majority of the East Aegean islands (Parmakelis & al. 2006; Triantis & al. 2008), has been isolated from the adjacent mainland (Asia Minor) for the last 0.8 My (Perissoratis & Conispoliatis 2003). Our results are in accordance with Sfenthourakis & Panitsa (2011), who stated that in small Aegean islands diversity at the whole-island scale is shaped mainly by heterogeneity among local communities. According to Hobohm's index, Chalki seems to be a plant-diversity hotspot in the phytogeographical region of the East Aegean Islands, since it has a higher Hobohm's  $\alpha$ -index value than Ikaria and Rhodos, two islands considered highly important in terms of phytogeography and endemism (Carlström 1986; Christodoulakis 1996b).

The palaeogeographical events that shaped the present-day South Aegean region are reflected in the occurrence of several taxonomically isolated and relict species in the flora of Chalki. Among these, *Allium chalkii* is the most prominent representative, since it constitutes a very rare, ancient, geographically isolated, single-island endemic confined to refuge habitats and considered as a member of the Tertiary Aegean flora because it bears some primitive morphological features (i.e. erect-divaricate-spathe, few-flowered inflorescence; Tzanoudakis & Kollmann 1991; Brullo & al. 2001). *Arenaria aegaea* Rech. f., *Asyneuma giganteum* (Boiss.) Bornm., *Centaurea lactucifolia* Boiss. and *Umbilicus albido-opacus* Carlström are probably Pliocene relicts (Carlström 1986), while the occurrence of *Lomelosia variifolia* (Boiss.) Greuter & Burdet on

Karpathos, Chalki and Rhodos seems to reflect the South Aegean palaeogeography during the early Pliocene, since Karpathos was joined with Chalki, Rhodos and Anatolia at that time (Daams & van der Weerd 1980). The distributions of *Colchicum macrophyllum* B. L. Burt and *Valeriana asarifolia* DuRoi. reflect the land-bridge connection that existed in the South Aegean during the Messinian salinity crisis (Carlström 1986; Schüle 1993; Cattaneo 2015): the former can be found on Kriti, Karpathos, Chalki and Rhodos, extending to SW Anatolia, while the latter is a South Aegean Island Arc endemic, occurring on Antikythira, Kriti, Karpathos and Chalki. On the other hand, *Campanula rhodensis* A. DC., *Dianthus fruticosus* subsp. *rhodius* (Rech. f.) Runemark, *Nigella arvensis* subsp. *brevifolia* Strid and *Symphytum circinale* may have resulted from random genetic drift during the climatic fluctuations and sea-level oscillations of the Pleistocene (Carlström 1986; Comes & al. 2008).

Nearly half (nine) of the endemic taxa found on Chalki correspond to one or two phytogeographical areas (Table 4), thus providing valuable information regarding the phytogeographical position of the study area, as the existence of biregional endemics is a good indication of phytogeographical connections between regions (Georghiou & Delipetrou 2010). It would be expected that Chalki shows higher affinities with the phytogeographical area of the Kiklades (Kik) since, according to Georghiou & Delipetrou (2010), the phytogeographical area of the East Aegean Islands (EAe) is chorologically closer connected to Kik than to that of Kriti and Karpathos (KK). While this may be true for the majority of the East Aegean Islands, our results demonstrate that Chalki is phytogeographically closer to KK, as we recorded three endemic taxa (*Asyneuma giganteum*, *Limonium sitiicum* and *Lomelosia variifolia*) occurring exclusively in KK and EAe and only one taxon (*Limonium ocymifolium*) occurring exclusively in Kik and EAe. More specifically, *A. giganteum* and *L. variifolia* are found only on Karpathos, Chalki and Rhodos, while *L. sitiicum* occurs only

in E Kriti, an islet N of Kasos (Raus 1990) and Chalki. Thus, Chalki and its adjacent islands (Rhodos and Syri) seem to have higher phytogeographical affinities with Kriti and Karpathos than with the Kiklades, concurring with previous studies in the area (Carlström 1986). This phenomenon could possibly be attributed to (1) the close palaeogeographical distance between these islands and Kriti and Karpathos during the Messinian salinity crisis (Hsü 1972), as well as during the Pliocene (Creutzburg 1963; Greuter 1970; Daams & van der Weerd 1980; Wiedenbein 1991c; Lymberakis & Poulakakis 2010) and the Pleistocene (Dermitzakis & de Vos 1987); and (2) the South Aegean Island Arc (of which Chalki is a part) being isolated from the rest of the Aegean region by extensive saline deserts or even saline/hypersaline lakes during the Messinian salinity crisis, even though dispersal through land was feasible at that time (Poulakakis & al. 2014).

Five very narrowly distributed taxa are present on Chalki (*Allium chalkii*, *Campanula rhodensis*, *Centaurea lactucifolia*, *Dianthus fruticosus* subsp. *rhodius* and *Umbilicus albido-opacus*), with *C. lactucifolia* being the most variable taxon, especially in terms of leaf and involucre appendage shape; it was once divided by Wagenitz (1975) into two varieties, var. *lactucifolia* and var. *halkensis* (Fors.-Major & Barbey) Wagenitz. Chalki is floristically more closely connected with Rhodos, since all of these taxa – except for *A. chalkii* – also occur on Rhodos. This phenomenon can be attributed to the two islands having been connected until the offset of the last glacial maximum (Lykousis 2009).

Chalki also seems to have close phytogeographical affinities with the Muğla province of Turkey, and more specifically, with the Marmaris (Datça) peninsula, since virtually all (apart from *Ophrys speculum* subsp. *regis-ferdinandii*) of its range-restricted East Mediterranean taxa occur also there. This phenomenon can be attributed to the cliff flora of the outer Marmaris (Datça) peninsula mainly resembling a slightly impoverished Aegean flora, since it hosts several typical Aegean species, such as *Campanula hagielia*, *Symphytum circinale* and *Verbas-cum propontideum* (Carlström 1986).

Finally, regarding the conservation status of *Allium chalkii*, its known population size and density and its area of occupancy were increased during the two years of monitoring, although the population at the type locality was apparently lost. Habitat loss due to human-induced activities constitutes the main threat faced by this taxon. Ex situ conservation seems to be an appropriate measure for *A. chalkii*, while an effort should be made to minimize the direct threats it is facing by informing the local residents about its rarity and importance.

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## References

- Akcakaya H. R. & Ferson S. 2007: RAMAS Red List 3.0. Threatened species classification under uncertainty. – Setauket: Applied Biomathematics, Inc. – Published at <https://www.ramas.com/redlist.htm>
- Arianoutsou M., Bazos I., Delipetrou P. & Kokkoris Y. 2010: The alien flora of Greece: taxonomy, life traits and habitat preferences. – *Biol. Invas.* **12**: 3525–3549.
- Arianoutsou M. & Margaris N. S. 1981: Producers and the fire cycle in a phrygic ecosystem. – Pp. 181–190 in: Margaris N. S. & Mooney H. A. (ed.), *Components of productivity of Mediterranean climate regions. Basic and applied aspects.* – The Hague, Boston, London: W. Junk Publishers.
- Arrhenius O. 1921: Species and area. – *J. Ecol.* **9**: 95–99.
- Barbero M., Bonin G., Loisel R. & Quézel P. 1990: Changes and disturbances of forest ecosystems caused by human activities in the western part of the Mediterranean basin. – *Vegetatio* **87**: 151–173.
- Bazos I. 2005: *Meleti tis chloridas kai tis vlastisis tis Lesvou* [Study of the flora and vegetation of Lesvos (East Aegean Islands, Greece)]. – Athens: Ph.D. thesis, University of Athens.
- Bergmeier E. & Strid A. 2014: Regional diversity, population trends and threat assessment of the weeds of traditional agriculture in Greece. – *Bot. J. Linn. Soc.* **175**: 607–623.
- Biel B. 2002: Contributions to the flora of the Aegean islands of Lesvos and Limnos, Greece. – *Willdenowia* **32**: 209–219.
- Biel B. & Tan. K. 2015: Reports 17–69. – Pp. 56–61 in: Vladimirov V., Dane F. & Tan K. (ed.), *New floristic records in the Balkans 26.* – *Phytol. Balcan.* **21**: 53–91.
- Blondel J., Aronson J., Bodiou J. Y. & Boeuf G. 2010: *The Mediterranean region. Biological diversity in space and time.* – Oxford: Oxford University Press.
- Böger H. & Dermitzakis D. M. 1987: Neogene palaeogeography in the central Aegean region. – *Ann. Hung. Geol. Inst.* **70**: 217–220.
- Boydak, M. & Barrow S. 1995: A new locality for *Phoenix* in Turkey: Gököy-Bödrum. – *Principes* **39(3)**: 117–122.
- Brofas G., Karetos G., Panitsa M. & Theocharopoulos M. 2001: The flora and vegetation of Gyalis island, SE Aegean, Greece. – *Willdenowia* **31**: 51–70.
- Brullo S., Pavone P. Salmeri C. 2001: *Allium brachyspathum* (*Alliaceae*), a new species from the island

- of Karpathos (S Aegean area, Greece). – *Bocconeia* **13**: 413–417.
- Carlström A. 1986: The phytogeographical position of Rodhos. – *Proc. Roy. Soc. Edinburgh, B, Biol. Sci.* **89B**: 79–88.
- Carlström A. 1987: A survey of the flora and phytogeography of Rodhos, Simi, Tilos and the Marmaris peninsula (SE Greece, SW Turkey). – Lund: Ph.D. thesis, University of Lund.
- Cattaneo C. 2015: *Valeriana asarifolia* Dufur. – P. 459 in: Raab-Straube E. & Raus Th. (ed.), *Euro+Med-Checklist Notulae*, 5 – *Willdenowia* **45**: 449–464.
- Christodoulakis D. 1996a: The flora of Ikaria (Greece, E. Aegean islands). – *Phyton (Horn)* **36**: 63–91.
- Christodoulakis D. 1996b: The phytogeographical distribution patterns of the flora of Ikaria (E Aegean, Greece) within the E Mediterranean. – *Flora* **191**: 393–399.
- Comes H. P., Tribsch A. & Bittkau C. 2008: Plant speciation in continental island floras as exemplified by *Nigella* in the Aegean archipelago. – *Philos. Trans., Ser. B* **363**: 3083–3096.
- Constantinidis Th. 2013: The flora of the Kastellorizo island group (East Aegean Islands, Greece): new records and comments. – *Fl. Medit.* **23**: 69–86.
- Creutzburg N. 1963: Palaeogeographic evolution of Crete from Miocene till our days. – *Cret. Ann.* **15/16**: 336–342.
- Daams R. & van der Weerd A. V. 1980: Early Pliocene small mammals from the Aegean island of Karpathos (Greece) and their palaeogeographic significance. – *Geol. Mijnbouw* **59**: 327–331.
- Dafis S., Papastergiadou E., Lazaridou E. & Tsiafouli M. 2001: Technical guide for the identification description and mapping of habitat types in Greece. – Thessaloniki: Greek Biotope/Wetland Centre.
- Davis P. H. (ed.) 1965–1985: *Flora of Turkey and the East Aegean Islands* **1** (1965), **2** (1967), **3** (1970), **4** (1972), **5** (1975), **6** (1978), **7** (1982), **8** (1984), **9** (1985). – Edinburgh: Edinburgh University Press.
- Davis P. H., Mill R. R. & Tan K. (ed.) 1988: *Flora of Turkey and the East Aegean Islands* **10** (Supplement). – Edinburgh: Edinburgh University Press.
- Dermitzakis M. D. & de Vos J. 1987: Faunal succession and the evolution of mammals in Crete during the Pleistocene. – *N. Jahrb. Geol. Palaeont. Abh.* **173**: 377–408.
- Dimopoulos P., Raus Th., Bergmeier E., Constantinidis Th., Iatrou G., Kokkini S., Strid A. & Tzanoudakis D. 2013: Vascular plants of Greece: an annotated checklist. – Berlin: Botanic Garden and Botanical Museum Berlin-Dahlem; Athens: Hellenic Botanical Society. – *Englera* **31**.
- Georghiou K. & Delipetrou P. 2010: Patterns and traits of the endemic plants of Greece. – *Bot. J. Linn. Soc.* **162**: 130–422.
- Gouvas M. & Sakellariou N. 2011: Climate and forest vegetation of Greece. – Athens: Institute of Environmental Research and Sustainable Development, National Observatory of Athens.
- Greuter W. 1970: Zur Paläogeographie und Florenschichte der südlichen Ägäis. – *Feddes Repert.* **81**: 233–242.
- Greuter W., Burdet H. M. & Long G. 1984–1989: *Med-Checklist. A critical inventory of vascular plants of the circum-mediterranean countries* **1** (1984), **3** (1986), **4** (1989). – Genève: Conservatoire et Jardin botaniques de la Ville de Genève; Berlin: Secrétariat Med-Checklist, Botanischer Garten und Botanisches Museum Berlin-Dahlem.
- Greuter W. & Raab-Straube E. von (ed.) 2008: *Med-Checklist. A critical inventory of vascular plants of the circum-mediterranean countries* **2**. – Palermo, Genève & Berlin: OPTIMA.
- Güner A., Özhatay N., Ekim T. & Başer K. H. C. (ed.) 2001 [“2000”]: *Flora of Turkey and the East Aegean Islands* **11** (Supplement 2). – Edinburgh: Edinburgh University Press.
- Hobohm C. 2000: Plant species diversity and endemism on islands and archipelagos, with special reference to the Macaronesian Islands. – *Flora* **195**: 9–24.
- Hobohm C. 2003: Characterization and ranking of biodiversity hotspots: centres of species richness and endemism. – *Biodivers. & Conservation* **12**: 279–287.
- Hsü K. J. 1972: Origin of saline giants: a critical review after the discovery of the Mediterranean evaporite. – *Earth.-Sci. Rev.* **8**: 371–396.
- IUCN 2012: *IUCN Red List categories and criteria. Version 3.1, ed. 2*. – Gland & Cambridge: IUCN. – Published at [http://www.iucnredlist.org/documents/redlist\\_cats\\_crit\\_en.pdf](http://www.iucnredlist.org/documents/redlist_cats_crit_en.pdf)
- IUCN Standards and Petitions Subcommittee 2010: *Guidelines for using the IUCN Red List categories and criteria. Version 8*. Prepared by the Standards and Petitions Working Subcommittee in March 2010. – Version 11 (February 2014) published at <http://www.iucnredlist.org/documents/RedListGuidelines.pdf>
- IUCN–CMP 2006: *Unified Classification of Conservation Actions. Version 1.0*. – Published at [http://www.conservationmeasures.org/wp-content/uploads/2010/04/IUCN-CMP\\_Unified\\_Actions\\_Classification\\_2006\\_06\\_01.pdf](http://www.conservationmeasures.org/wp-content/uploads/2010/04/IUCN-CMP_Unified_Actions_Classification_2006_06_01.pdf)
- Kagiampaki A., Triantis K., Vardinoyannis K. & Mylonas M. 2011: Factors affecting species richness and endemism in the South Aegean (Greece). – *J. Biol. Res.* **16**: 282–295.
- Kallimanis A. S., Bergmeier E., Panitsa M., Georghiou K., Delipetrou P. & Dimopoulos P. 2010: Determinants for total and endemic species richness in a continental archipelago. – *Biodivers. & Conservation* **19**: 1225–1235.
- Kougioumoutzis K., Simaiakis S. M. & Tiniakou A. 2014a: Network biogeographical analysis of the central Aegean archipelago. – *J. Biogeogr.* **41**: 1848–1858.

- Kougioumoutzis K., Tiniakou A., Georgiou O. & Georgiadis Th. 2012: Contribution to the flora of the South Aegean Volcanic Arc: Anafi Island (Kiklades, Greece). – *Willdenowia* **42**: 127–141.
- Kougioumoutzis K., Tiniakou A., Georgiou O. & Georgiadis Th. 2014b: Contribution to the flora of the South Aegean Volcanic Arc: Kimolos Island (Kiklades, Greece). – *Edinburgh J. Bot.* **71**: 135–160.
- Kougioumoutzis K., Tiniakou A., Georgiou O. & Georgiadis Th. 2015: Contribution to the flora and biogeography of the Kiklades: Folegandros Island (Kiklades, Greece). – *Edinburgh J. Bot.* **72**: 391–412.
- Kypriotakis Z. 1998: Contribution to the study of the chasmophytic flora of Crete. – Patras: Ph.D. thesis, University of Patras.
- Kypriotakis Z. & Tzanoudakis, D. 2001: Contribution to the study of the Greek insular flora: The chasmophytic flora of Crete. – *Bocconea* **13**: 495–503.
- Livianiou-Tiniakou A., Christodoulakis D., Georgiou O. & Artelari R. 2003: Floristic dynamics in correlation with the type of substrate and human activities: the example of Serifos (Kiklades Islands, Greece). – *Fresenius Environm. Bull.* **12**: 1520–1529.
- Lykousis V. 2009: Sea-level changes and shelf break prograding sequences during the last 400 ka in the Aegean margins: Subsidence rates and palaeogeographic implications. – *Continental Shelf Res.* **29**: 2037–2044.
- Lymberakis P. & Poulakakis N. 2010: Three continents claiming an archipelago: the evolution of Aegean's herpetofaunal diversity. – *Diversity* **2**: 233–255.
- Maroukian H., Pavlopoulos K. & Fokas E. 2004: Geomorphological observations in Halki Island, Dodecanese – Proc. 7<sup>th</sup> Panhellenic Geogr. Congr. **1**: 271–277.
- Naveh Z. 1974: Effects of fire in the Mediterranean region. – In: Kozłowski T. T. & Ahlgren C. E. (ed.), *Fire and ecosystems*. – New York: Elsevier Inc.
- Panitsa M. 1997: Contribution to the knowledge of the East Aegean islands' flora and Vegetation. – Patras: Ph.D. thesis, University of Patras.
- Panitsa M., Dimopoulos P., Iatrou G. & Tzanoudakis D. 1994: Contribution to the study of the Greek flora: flora and vegetation of the Enousses (Oinousses) islands (E Aegean area). – *Flora* **189**: 367–374.
- Panitsa M., Snogerup B., Snogerup S. & Tzanoudakis D. 2003: Floristic investigation of Lemnos island (NE Aegean area, Greece). – *Willdenowia* **33**: 79–105.
- Panitsa M., Trigas P., Iatrou G. & Sfenthourakis S. 2010: Factors affecting plant species richness and endemism on land-bridge islands – An example from the East Aegean archipelago. – *Acta Oecol.* **36**: 431–437.
- Panitsa M. & Tzanoudakis D. 1998: Contribution to the study of the Greek flora: flora and vegetation of the islands Agathonisi and Pharmakonisi (East Aegean area, Greece). – *Willdenowia* **28**: 95–116.
- Panitsa M. & Tzanoudakis D. 2001: A floristic investigation of the islet groups Arki and Lipsi (East Aegean area, Greece). – *Folia Geobot.* **36**: 265–279.
- Panitsa M. & Tzanoudakis D. 2010: Floristic diversity on small islands and islets: Leros islets' group (East Aegean area, Greece). – *Phytol. Balcan.* **16**: 271–284.
- Panitsa M., Tzanoudakis D. & Sfenthourakis S. 2008: Turnover of plants on small islets of the eastern Aegean Sea within two decades. – *J. Biogeogr.* **35**: 1049–1061.
- Panitsa M., Tzanoudakis D., Triantis K. A. & Sfenthourakis S. 2006: Patterns of species richness on very small islands: the plants of the Aegean archipelago. – *J. Biogeogr.* **33**: 1223–1234.
- Papatsou S. 1974: Flora and vegetation of Nisiros island and the surrounding islets. – Patras: Ph.D. thesis, University of Patras.
- Parmakelis A., Stathi I., Spanos L., Louis C. & Mylonas M. 2006: Phylogeography of *Iurus dufourei* (Brullé, 1832) (Scorpiones, Iuridae). – *J. Biogeogr.* **33**: 251–260.
- Perissoratis C. & Conispoliatis N. 2003: The impacts of sea-level changes during latest Pleistocene and Holocene times on the morphology of the Ionian and Aegean seas (SE Alpine Europe). – *Marine Geol.* **196**: 145–156.
- Poulakakis N., Kapli P., Lymberakis P., Trichas A., Vardinoyannis K., Sfenthourakis S. & Mylonas M. 2014: A review of phylogeographic analyses of animal taxa from the Aegean and surrounding regions. – *J. Zool. Syst. Evol. Res.* **53**: 18–32.
- QGIS Development Team. 2015: QGIS Geographic Information System. Open Source Geospatial Foundation Project. – Published at <http://qgis.osgeo.org>
- R Core Team 2015: R: A language and environment for statistical computing. – Vienna: R Foundation for Statistical Computing. – Published at <https://www.r-project.org/>
- Raus Th. 1990 [“1989”]: Die Flora von Armathia und der Kleininseln um Kasos (Dodekanes, Griechenland). – *Bot. Chron. (Patras)* **9**: 19–39.
- Raus Th. 2012: Gefäßpflanzen von Milos (Kykladen, Griechenland) – eine floristische Handreichung. – *Verh. Zool.-Bot. Ges. Österreich* **148/149**: 197–235.
- Rechinger K. H 1944 [“1943”]: Flora aegaea. Flora der Inseln und Halbinseln des ägäischen Meeres. – *Denkschr. Akad. Wiss. Wien, Math.-Naturwiss. Kl.* **105(1)**.
- Schüle W. 1993: Mammals, vegetation and the initial human settlement of the Mediterranean islands: a palaeoecological approach. – *J. Biogeogr.* **20**: 399–412.
- Sfenthourakis S. & Panitsa M. 2011: From plots to islands: species diversity at different scales. – *J. Biogeogr.* **39**: 750–759.
- Sfenthourakis S. & Triantis K. A. 2009: Habitat diversity, ecological requirements of species and the small island effect. – *Diversity & Distrib.* **15**: 131–140.
- Strid A. 1996: Phytogeographia aegaea and the Flora Hellenica project. – *Ann. Naturhist. Mus. Wien* **98B**: 279–289.
- Strid A. & Tan K. (ed.) 1997: *Flora hellenica* **1**. – Königstein: Koeltz Scientific Books.

- Strid A. & Tan K. (ed.) 2003 [“2002”]: Flora hellenica **2**. – Ruggell: A. R. G. Gantner.
- Tan K., Iatrou G. & Johnsen B. 2001: Endemic plants of Greece. The Peloponnese. – Copenhagen: Gad Publishers.
- Thiers B. [continuously updated]. Index Herbariorum: A global directory of public herbaria and associated staff. New York Botanical Garden’s Virtual Herbarium. – Published at <http://sweetgum.nybg.org/science/ih/> [last accessed 21 Mar 2016].
- Thymakis N. 2009: *Phoenix theophrasti* Greuter. – Pp. 256–258 in: Phitos D., Constantinidis Th. & Kamari G. (ed.) 2009: The Red Data Book of rare and threatened plants of Greece **2** E–Z. – Patras: Hellenic Botanical Society.
- Triantis K. A. & Mylonas M. 2009: Greek islands, biology. – Pp. 388–392 in: Gillespie R. & Glague D. A. (ed.), Encyclopaedia of islands. – Berkeley: University of California Press.
- Triantis K. A., Vardinoyannis K. & Mylonas M. 2008: Biogeography, land snails and incomplete datasets: the case of three island groups in the Aegean Sea. – *J. Nat. Hist.* **42**: 467–490.
- Trigas P., Panitsa M. & Tsiftsis S. 2013: Elevational gradient of vascular plant species richness and endemism in Crete – The effect of post-isolation mountain uplift on a continental island system. – *PLoS ONE* **8**: e59425.
- Turland N. J., Chilton L. & Press J. R. 1993: Flora of the Cretan area: annotated checklist & atlas. – London: The Natural History Museum & HMSO.
- Tutin T. G., Burges N. A., Chater A. O., Edmondson J. R., Heywood V. H., Moore D. M., Valentine D. H., Walters S. M. & Webb D. A. (ed.) 1993: Flora europaea **1** *Psilotaceae* to *Platanaceae*, ed. 2. – Cambridge: Cambridge University Press.
- Tutin T. G., Heywood V. H., Burges N. A., Moore D. M., Valentine D. H., Walters S. M. & Webb D. A. (ed.) 1964–1980: Flora europaea **1** (1964), **2** (1968), **3** (1972), **4** (1976), **5** (1980). – Cambridge: Cambridge University Press.
- Tzanoudakis D. & Kollmann F. 1991: *Allium chalkii* (*Liliaceae*), a new species from the Eastern Aegean island of Chalki (Greece). – *Israel J. Bot.* **40**: 61–64.
- Tzanoudakis D., Panitsa M., Trigas P. & Iatrou G. 2006: Floristic and phytosociological investigation of the island Antikythera and nearby islets (SW Aegean, Greece). – *Willdenowia* **36**: 285–301.
- Wagenitz, G. 1975: *Centaurea*. – Pp. 465–585. – In: Davis P. H. (ed.), Flora of Turkey and the East Aegean Islands **5**. – Edinburgh: Edinburgh University Press.
- Whittaker R. J. & Fernández-Palacios J. M. (ed.) 2007: Island biogeography. Ecology, evolution and conservation. – Oxford: Oxford University Press.
- Wickham H. 2009: ggplot2: elegant graphics for data analysis. – New York: Springer.
- Wiedenbein F. W. 1991: Biogeographic patterns of the Aegean region and their geological origin. – *Bull. Geol. Soc. Greece* **25**: 423–435.
- Zervou S., Raus Th. & Yannitsaros A. 2009: Additions to the flora of the island of Kalimnos (SE Aegean, Greece). – *Willdenowia* **39**: 165–177.

## Appendix

Only taxa new to Chalki Island are listed.

Life forms:

- C = Chamaephyte
- G = Geophyte
- H = Hemicryptophyte
- P = Phanerophyte
- T = Therophyte

Chorological groups:

Widely distributed taxa:

- Eu = European
- EA = European-SW Asian
- ES = Euro-Siberian
- Pt = Paleotemperate
- Ct = Circumtemperate
- ST = Subtropical-Tropical
- Co = Cosmopolitan

Mediterranean taxa:

- EM = Eastern Mediterranean
- Me = Mediterranean
- MA = Mediterranean-Atlantic
- ME = Mediterranean-European
- MS = Mediterranean-SW Asian

Balkan taxa:

- Bk = Balkan
- BI = Balkan-Italian
- BA = Balkan-Anatolian

Endemic = Endemic taxa

Alien taxa; name and origin given in [square brackets], as follows:

- Neotrop. = Neotropical
- Paleotrop. = Paleotropical
- N-Am. = North American
- S-Am. = South American
- S-Afr. = South African
- Austr. = Australian
- W-Austr. = West Australian

## Collection sites:

- 1: 36°13'43.7"N, 27°35'22.9"E, 370 m
- 2: 36°13'13.3"N, 27°34'34.4"E, 80 m
- 3: 36°13'43.9"N, 27°31'34.7"E, 180 m
- 4: 36°14'42.0"N, 27°36'00.8"E, 60 m
- 5: 36°14'07.5"N, 27°34'14.4"E, 460 m
- 6: 36°13'26.8"N, 27°37'14.1"E, 18 m
- 7: 36°13'19.0"N, 27°31'53.6"E, 283 m
- 8: 36°13'36.0"N, 27°32'20.0"E, 402 m
- 9: 36°13'02.4"N, 27°34'19.3"E, 17 m
- 10: 36°13'26.9"N, 27°36'38.8"E, 47 m
- 11: 36°13'59.4"N, 27°32'23.2"E, 293 m
- 12: 36°14'03.9"N, 27°37'02.9"E, 40 m
- 13: 36°14'13.1"N, 27°34'54.8"E, 302 m
- 14: 36°13'49.6"N, 27°33'02.4"E, 316 m
- 15: 36°12'58.2"N, 27°36'47.3"E, 43 m
- 16: 36°13'31.1"N, 27°34'50.3"E, 308 m
- 17: 36°13'38.9"N, 27°36'33.5"E, 103 m
- 18: 36°13'11.9"N, 27°35'45.3"E, 130 m
- 19: 36°14'09.9"N, 27°36'11.9"E, 318 m
- 20: 36°13'20.2"N, 27°36'06.4"E, 24 m
- 21: 36°13'29.1"N, 27°34'04.0"E, 495 m
- 22: 36°13'36.9"N, 27°33'16.1"E, 403 m
- 23: 36°13'54.1"N, 27°36'27.9"E, 159 m
- 24: 36°13'18.4"N, 27°35'19.8"E, 156 m

## Collection dates:

- a: 17–22 Apr 2012
- b: 14–22 Nov 2012
- c: 1–10 Mar 2013
- d: 1–9 May 2013
- e: 14–22 Apr 2014

## Recorder information:

TS = M. Tsakiri [with collection number]  
 obs. = field observation  
 phot. = photograph

## Ferns

**Pteridaceae**

*Anogramma leptophylla* (L.) Link – T, Co; 24, d, TS 294.

**Angiosperms****Acanthaceae**

*Acanthus spinosus* L. – H, Me; 24, d, TS 748.

**Agavaceae**

[*Agave americana* L.] – P, [N-Am.]; 20, a, TS phot.

**Aizoaceae**

[*Carpobrotus edulis* (L.) N. E. Br.] – C, [S-Afr.]; 20, a, TS obs.

**Amaryllidaceae**

*Allium amethystinum* Tausch – G, EM; 17, d, TS 664.

*Allium subhirsutum* L. subsp. *subhirsutum* – G, Me; 11, d, TS 666; 13, d, TS 749; 5, d, TS 750.

*Pancreaticum maritimum* L. – G, Me; 20, b, TS 754.

**Anacardiaceae**

*Pistacia terebinthus* subsp. *palaestina* (Boiss.) Engl. – P, EM; 24, a, TS 409.

**Apiaceae**

*Crithmum maritimum* L. – C, ME; 20, b, TS 169; 12, b, TS 170.

*Smyrniolum creticum* Mill. – H, EM; 11, e, TS obs.; 13, e, TS obs.

*Smyrniolum olusatrum* L. – H, MA; 10, c, TS 186.

*Torilis arvensis* subsp. *neglecta* (Spreng.) Thell. – T, ME; 20, a, TS 186.

**Araceae**

*Arum creticum* Boiss. & Heldr. – G, EM; 6, d, TS phot.; 7, d, TS phot.; 13, d, TS obs.; 14, d, TS obs.

**Arecaceae**

*Phoenix theophrasti* Greuter – P, EM; 10, a, TS obs.; 20, c, TS obs.

**Asparagaceae**

*Asparagus acutifolius* L. – C, Me; 6, b, TS 681; 15, b, TS 744.

**Asteraceae**

*Anthemis macrotis* (Rech. f.) Oberpr. & Vogt – T, EM; 9, a, TS 286; 12, a, TS 287; 20, a, TS 289; 8, d, TS 290.

*Cichorium intybus* L. – H, EA; 8, d, TS 269; 24, d, TS 271.

*Dittrichia graveolens* (L.) Greuter – T, Me; 9, b, TS 768.

*Dittrichia viscosa* (L.) Greuter – C, Me; 15, b, TS 769.

*Filago pygmaea* L. – T, Me; 20, d, TS 226; 15, d, TS obs.

*Lactuca acanthifolia* (Willd.) Boiss. – C, EM; 11, e, TS 766; 13, e, TS phot.; 18, e, TS obs.; 7, e, TS obs.; 21, e, TS obs.; 22, e, TS obs.; 23, e, TS obs.

*Picnomon acarna* (L.) Cass. – T, Pt; 6, b, TS 248.

*Reichardia intermedia* (Sch. Bip.) Samp. – T, Me; 23, c, TS 278.

*Reichardia picroides* (L.) Roth – H, Me; 15, d, TS 277.

*Scorzonera mollis* M. Bieb. subsp. *mollis* – H, EA; 20, d, TS 246; 8, d, TS 247.

*Senecio leucanthemifolius* Poir. – T, Me; 24, c, TS phot.

*Senecio vulgaris* L. – T, Pt; 21, c, TS 284; 20, c, TS 285.

*Taraxacum hellenicum* Dahlst. – H, Me; 24, c, TS 224.

*Taraxacum scolopendrinum* Dahlst. – H, Me; 3, b, TS 207; 15, b, TS 209; 12, b, TS 210.

**Boraginaceae**

*Buglossoides arvensis* subsp. *sibthorpiana* (Griseb.) R. Fern. – T, EA; 17, c, TS 742; 8, c, TS phot.; 3, c, TS phot.

*Echium angustifolium* Mill. subsp. *angustifolium* – H, EM; 20, d, TS 741; 15, d, TS phot.

*Myosotis incrassata* Guss. – T, Me; 21, c, TS 743; 8, c, TS phot.

#### **Brassicaceae**

*Arabis verna* (L.) W. T. Aiton; 8, c, TS 507; 24, c, TS 508; 12, c, TS 509.

*Malcolmia chia* (L.) DC. – T, EM; 20, a, TS 526; 22, d, TS 525.

*Matthiola tricuspidata* (L.) R. Br. – T, Me; 20, d, TS 528; 20, d, 529; 12, d, TS obs.; 15, d, TS obs.

*Raphanus raphanistrum* L. subsp. *raphanistrum* – T, EA; 12, d, TS 534.

*Sinapis alba* L. subsp. *alba* – T, ME; 10, c, TS 511.

#### **Cactaceae**

[*Opuntia ficus-indica* (L.) Mill.] – P, [Neotrop.]; 20, a, TS phot.

#### **Campanulaceae**

*Campanula erinus* L. – T, ME; 8, d, TS 628; 8, d, TS 629; 8, d, TS 630.

#### **Caryophyllaceae**

*Silene behen* L. – T, ME; 17, c, TS 364; 12, c, TS 366.

#### **Cistaceae**

*Cistus creticus* L. – C, Me; 17, c, TS 403.

#### **Colchicaceae**

*Colchicum pusillum* Sieber – G, EM; 8, b, TS 686; 3, b, TS 740.

#### **Crassulaceae**

*Umbilicus rupestris* (Salisb.) Dandy – G, MA; 24, d, TS 738; 24, d, TS 739.

#### **Cucurbitaceae**

*Ecballium elaterium* (L.) A. Rich. – G, MS; 10, d, TS 333; 10, e, TS 334.

#### **Euphorbiaceae**

*Euphorbia helioscopia* L. – T, Co; 9, c, TS 751.

[*Ricinus communis* L.] – P, [Paleotrop.]; 20, a, TS obs.

#### **Fabaceae**

*Hymenocarpus circinnatus* (L.) Savi – T, Me; 20, a, TS 478; 12, c, TS 479.

*Lathyrus amphicarpos* L. – T, Me; 16, c, TS 467.

*Lathyrus annuus* L. – T, MS; 24, d, TS 447.

*Ononis pubescens* L. – T, Me; 20, a, TS 453.

*Spartium junceum* L. – P, Me; 10, a, TS 486.

*Trifolium boissieri* Guss. – T, EM; 20, a, TS 441; 20, d, TS 482.

#### **Fagaceae**

*Quercus aucheri* Jaub. & Spach – P, EM; 18, e, TS 777.

#### **Gentianaceae**

*Blackstonia perfoliata* (L.) Huds. subsp. *perfoliata* – T, ME; 17, d, TS 752.

#### **Geraniaceae**

*Geranium molle* L. – T, Pt; 17, c, TS obs.

#### **Hyacinthaceae**

*Bellevalia dubia* subsp. *boissieri* (Freyn) Feinbrun – G, Me; 12, c, TS 680.

*Bellevalia trifoliata* (Ten.) Kunth – G, Me; 17, a, TS 679; 20, c, TS 734; 1, c, TS 735.

*Muscari comosum* (L.) Mill. – G, ME; 3, d, TS 671; 20, a, TS 733.

*Muscari neglectum* Ten. – G, EA; 21, a, TS 676; 5, a, TS 723.

*Prospero autumnale* (L.) Speta – G, Me; 6, b, TS 687, 15, b, TS 688, 24, b, TS 689; 12, b, TS 736.

#### **Iridaceae**

*Crocus tournefortii* J. Gay – G, Endemic; 3, b, TS 643; 8, b, TS 644.

*Romulea tempskyana* Freyn – G, EM; 6, c, TS 746; 17, c, TS 747.

#### **Lamiaceae**

*Lamium amplexicaule* L. – T, Pt; 24, c, TS 731; 12, c, TS 129.

*Sideritis purpurea* Benth. – T, Bk; 20, a, TS 110; 20, a, TS 117.

*Teucrium divaricatum* Heldr. subsp. *divaricatum* – C, EM; 11, d, TS 121; 13, d, TS 753; 5, d, TS phot.

#### **Liliaceae**

*Gagea peduncularis* (J. Presl & C. Presl) Pascher – G, Me; 12, c, TS 728; 14, c, TS 729; 21, c, TS obs.; 22, c, TS phot.

#### **Malvaceae**

*Malva nicaeensis* All. – T, Me; 20, a, TS 725; 20, a, TS 726.

*Malva punctata* (All.) Alef. – T, Me; 20, d, TS 727.

#### **Mimosaceae**

[*Acacia saligna* (Labill.) H. Wendl.] – P, [W-Austr.]; 20, a, TS 444.

#### **Myrtaceae**

[*Eucalyptus camaldulensis* Dehnh.] – P, [Austr.]; 20, a, TS 416.

#### **Orchidaceae**

*Anacamptis papilionacea* (L.) R. M. Bateman & al. – G, MS; 7, d, TS 609; 7, d, TS phot.

*Ophrys ferrum-equinum* Desf. – G, BA; 20, c, TS phot.

*Ophrys fusca* Link – G, Me; 12, c, TS 610; 12, c, TS phot.

*Ophrys lutea* Cav. – G, Me; 12, c, TS 612; 19, c, TS phot.



- Ophrys speculum* subsp. *regis-ferdinandii* (Acht. & Kellerer ex Renz) Soó. – G, EM; 12, c, *TS 608*; 12, c, *TS phot.*  
*Ophrys tenthredinifera* Willd. – G, Me; 3, c, *TS phot.*  
*Orchis anatolica* Boiss. – G, EM; 20, a, *TS 605.*  
*Spiranthes spiralis* (L.) Chevall. – G, EA; 15, b, *TS 724.*
- Orobanchaceae**  
*Phelipanche ramosa* (L.) Pomel – T, Pt; 20, c, *TS 133.*
- Oxalidaceae**  
[*Oxalis pes-caprae* L.] – G, [S-Afr.]; 21, c, *TS 412.*
- Papaveraceae**  
*Papaver apulum* Ten. – T, BI; 20, a, *TS 146.*
- Plantaginaceae**  
*Plantago indica* L. – T, MS; 10, a, *TS 150*; 17, a, *TS 152*; 15, a, *TS 154.*
- Plumbaginaceae**  
*Limonium ocymifolium* (Poir.) Kuntze – C, Endemic; 15, b, *TS 132.*  
*Limonium proliferum* (d'Urv.) Erben & Brullo – C, Endemic; 4, d, *TS 130.*  
*Limonium sitiacum* Rech. f. – C, Endemic; 12, c, *TS 131.*
- Poaceae**  
*Aegilops comosa* Sm. – T, EM; 5, d, *TS 5.*  
*Avenula pubescens* (Huds.) Dumort. subsp. *pubescens* – H, EA; 6, d, *TS 31.*  
*Bromus hordeaceus* L. – T, Co; 10, a, *TS 33.*  
*Bromus lanceolatus* Roth – T, Pt; 15, a, *TS 32.*  
*Bromus rigidus* Roth – T, ST; 20, d, *TS 17*; 20, c, *TS 29*; 10, c *TS 61*; 10, a, *TS 68.*  
*Hordeum vulgare* L. – T, Me; 10, c, *TS 23*; 20, a, *TS 24.*  
*Piptatherum miliaceum* (L.) Coss. subsp. *miliaceum* – C, Me; 16, d, *TS 65.*  
*Poa bulbosa* L. – H, Pt; 3, d, *TS 30.*  
*Setaria adhaerens* (Forssk.) Chiov. – T, Ct; 10, b, *TS 69.*
- Polygalaceae**  
*Polygala venulosa* Sm. – H, EM; 17, c, *TS 721.*
- Primulaceae**  
*Anagallis foemina* Mill. – T, EA; 20, a, *TS 719*; 12, a, *TS 720.*  
*Cyclamen graecum* subsp. *anatolicum* Grey-Wilson – G, EM; 10, c, *TS 698.*
- Ranunculaceae**  
*Anemone coronaria* L. – G, Me; 6, c, *TS 415.*  
*Ficaria verna* subsp. *ficariiformis* (Rouy & Foucaud) Soó – G, Me; 21, c, *TS 424.*  
*Ranunculus creticus* L. – H, EM; 8, c, *TS 417*; 24, c, *TS 419.*
- Rosaceae**  
[*Prunus dulcis* (Mill.) D. A. Webb] – P, [SW & C-As.]; 12, b, *TS 317*; 20, b, *TS obs.*
- Rubiaceae**  
*Galium aparine* L. – T, EA; 20, c, *TS 571.*
- Scrophulariaceae**  
*Verbascum sinuatum* L. – H, MS; 10, d, *TS 715*, 12, d, *TS 716.*
- Solanaceae**  
[*Nicotiana glauca* R. C. Graham] – P, [S-Am.]; 15, c, *TS 635*; 2, c, *TS phot.*; 10, c, *TS phot.*
- Tamaricaceae**  
*Tamarix smyrnensis* Bunge – P, EA; 20, a, *TS 655*; 10, a, *TS 656.*
- Valerianaceae**  
*Centranthus ruber* (L.) DC. – H, Me; 10, e, *TS 413.*  
*Valerianella discoidea* (L.) Loisel. – T, Me; 20, c, *TS 415.*  
*Valerianella obtusiloba* Boiss. – T, EM; 20, c, *TS 414*; 12, c, *TS 694*, 17, c, *TS 709.*
- Veronicaceae**  
*Kickxia elatine* subsp. *crinita* (Mabille) Greuter – T, Me; 20, a, *TS 754*, 12, a, *TS 755.*

## Willdenowia

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