Contribution to the knowledge of vascular flora on Astypalea Island (Dodecanese, Greece)

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Abstract. The aim of this paper is to contribute further knowledge of the vascular flora of the Aegean island of Astypalea (Dodecanese, Greece). The island, which acts as a bridge between the Kiklades and the eastern Aegean, is administrated as part of the Dodecanese Archipelago but shows a remarkable presence of Cycladic elements, both in terms of fauna and flora. Astypalea, home to a high number of Greek endemics and of rare species with a restricted range, is part of the floristic region of the Kiklades (Kik). An analysis of endemic taxa occurring on the island, despite its chorological vicinity to the East Aegean Islands (EAe), shows more phytogeographic connections with Crete and Karpathos (KK). For the first time, 26 new taxa have been reported for the island.

Key words: Astypalea, endemism, floristic regions, Greece, Ofidoussa, phytogeographic connections

Introduction

Astypalea is the fifth largest and westernmost island of the Dodecanese Archipelago. It is located southwest of Kos, from which it is distanced 23 nm; southeast of Amorgos (23 nm); north of Anafi (27 nm); and west of Rhodes (96 nm) (Theodosopoulos 2005). The geographical coordinates are: 26°18'56.07"E, 36°33'07.63"N. There are only four villages on the island: Hora (the chief town), Analipsi/Maltezana, Livadhi and Vathy. Astypalea, with numerous smaller uninhabited offshore islets (the largest of which are Syrna and Ofidoussa), forms the municipal district of Astypalea, which is part of the Kalymnos Regional Unit. Twelve of these islets (Kounoupi, Koutsomytis, Ofidoussa, Tighani, Moni, Hondhri, Fteno, Fokonisia, Lighno, Hondhropoulo, Aghia Kyriaki, and Pontikoussa), with the eastern half of Astypalea (Mesa Nisi) constitute a protected area included in the Natura 2000 Network (GR 4210009), due to the presence of highly representative and exclusive habitats (www.ypeka.gr). The site in question, like the rest of the island of Astypalea, is of high biogeographical value. The unique geographical position of Astypalea, acting as a bridge between the Kiklades and the Dodecanese, favored the presence of Cycladic and eastern floristic and faunistic elements. However it shows many specific features of South Aegean. The entire island is considered an important area for birds. The *Posidonia oceanica* seabeds, as well as the ecosystems of rocky coasts with rare and endemic plants and the presence of several coastal inlets, that host rare animal species such as the monk seal (*Monachus monachus*) and the sea turtle (*Caretta caretta*), make Astypalea one of the most representative sites in the Aegean Sea and Southeast Mediterranean Sea.

Physical characterization (geography, geology, climate)

Astypalea consists of two parts: a western half (Exo Nisi) and an eastern one (Mesa Nisi), joined by a narrow isthmus (Steno) 105 m wide (Fig. 1). This feature gives the island an unusual butterfly shape. The isthmus resulted from the collapse of large portions of the land in the northern and in southern parts during the

tectonic movements over the geological era. Astypalea has an area of 96.42 km². The coastline (66 km) is highly articulated with bays, steep cliffs and capes. The plains in Astypalea (Vathy, Aghrelidhi, Maltezana and Livadhi) were formed by alluvial deposits and tectonic movements. Astypalea is essentially hilly and the orographic axis is oriented in the northwest-southeast direction. In the western half, the south-northwest direction of the orographic axis is clearly visible through the highest reliefs, which are Athymadhari (300 m), Koutela (431 m), Vardhia (482 m), Ftera (427 m), Patelos (329 m), and Vighla (125 m). This type of orography in the western half has led to the formation of very steep coastlines, mainly constituted by limestone rock. The inner parts of the most important bays like Vatses, Kaminakia, Pachia Ammos, Zafeiri, Aghrelidhi, Marmari, Pera Ghialos, and Livadhi are characterized by thick sandstone formations, which are the result of accumulated fluvial and marine deposits. In the eastern half, the orographic axis is oriented in the southeast-northwest direction, starting from the Kastellanos (366 m) relief and ending at Agios Thomas (200 m) (Leontaris 1973). In the eastern half of Astypalea, the coastline is less steep. The Astypalea island group is one of the most isolated in the Aegean Sea, lying at its center, and comprising a transitional zone between the Kiklades and East Aegean Islands. Astypalea was connected with the Kiklades during the upper Miocene (Triantis & al. 2008) and probably detached between the Middle Miocene and the Pliocene. The islets neighboring Astypalea were probably formed during the Holocene and the level of isobaths within 200 m is a clear indication that a connection existed in the past between these islands and Astypalea. Only the islands of Ofidoussa and Pontikoussa (northwest) seem to be older (Triantis & al. 2008). Astypalea is made up mainly of limestone rock: in the eastern part or Mesa Nisi, the north-northeast end is mainly very hard Upper Cretaceous limestone, which constitutes the oldest layers of the island (Martelli 1913; Desio 1931; Christodoulou 1966); in the western part, or Exo Nisi, the south-southwest end consists of Eocene limestone. This calcareous nature has given rise to karst features and the formation of numerous caves. The area between the orographic series of the Mesa and Exo Nisi is constituted mainly of flysch. Even most of the small islands around Astypalea are limestone, except for Fokonisia and Diapori (Leontaris 1973; Triantis & al. 2008).

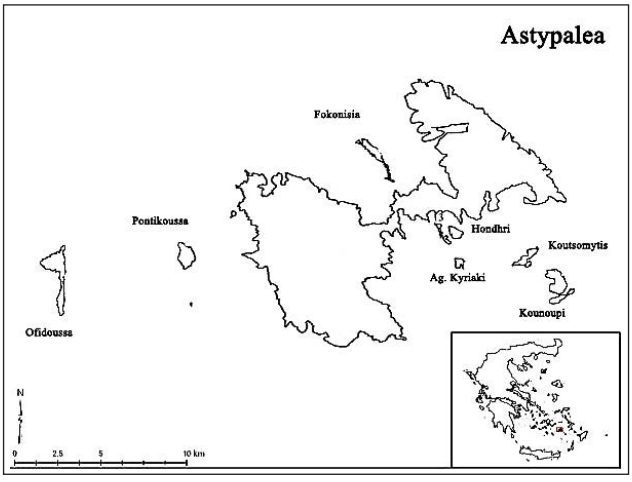

Fig. 1. Map of Astypalea and nearby islets.

Astypalea is mainly dry, however, the karstic nature of limestone, natural sloping rocks, and the encounter between limestone and flysch, have all given life to water sources and to groundwater, although this is shallow. The western part is characterized by moderate superficial hydrography considering the presence of springs like Moura and Aghios Ioannis and still-active streams, such as Aghios Ioannis and Vatses, which flow into the eponymous bays. In the eastern part there are no active streams. Around the 1990s using several watercourses in the area and sufficiently important groundwater, a reservoir closed by a dam was built in the central part of the Exo Nisi, near Livadhi village, with a capacity of 1,000,000 cubic meters and a depth of 25 meters, used to supply water to Astypalea (Theodosopoulos 2005).

From a climatic point of view Astypalea is typically Mediterranean, with mild, rainy winters and dry summers. The extrapolated data from the National Meteorological Service (EMY) (http://www.hnms.gr/) from 1977 to 2013, reported an annual average temperature of 19.27 °C for Astypalea. The average minimum temperature was recorded in February with values of 7.73 °C and the average maximum in July, with values of 32.09 °C. The average annual values for relative humidity are around 70.13 %, and average annual rainfall recorded from 1985 to 2012 is around 400 mm.

Earlier investigations

Floristic surveys in the island of Astypalea began in the 1800s. The first botanist to carry out research on the island was Dumont d'Urville (1822), collecting 45 taxa in 1819. Later, in 1886, Forsyth-Major & Bar-

bey (1893) gathered other vascular plants on the island. In 1912, Vaccari listed 17 species (Béguinot & Vaccari 1912) on Astypalea and the nearby islet Lighno (southeast). The geologist Martelli (1913) and the Italian botanist Fiori (1939) also reported plants from Astypalea. This sporadic research was followed in 1935 by botanical exploration led by Rechinger (1943; Rechinger & Rechinger-Moser 1951). In 1960, Runemark and Nordenstam assembled botanical collections on Astypalea and Ofidoussa. Since the 1990s, the island has been subject of several investigations. Georgiou (1990) identified a new variety of *Anthemis scopulorum* (*Anthemis scopulorum* var. *ofidoussa*). Salmeri (1998), on the basis of material collected on Astypalea by Brullo (University of Catania), described a new species of *Allium*: *Allium brulloi*. In the same years, Delforge (1997) published an article on the island's orchids. Lastly, in the 2000s, Sfikas and Tan (2013) researched the islands nearest to Astypalea, like Ofidoussa, Kounoupi and Pontikoussa, confirming for the first two, species previously reported by Runemark and Nordenstam, and reporting for Pontikoussa a new endemic species, *Allium pilosum*, already described for the Cycladic island of Kimolos (Sibthorp & Smith 1809; Brullo & al. 2001). Recently Tan, Biel and Sfikas described a new species for science, *Legousia snogerupii*, found on Astypalea and nearby islands (Tan & al. 2015). Brullo & Erben (2016) have revised genus *Limonium* in Greece based on morphological and morphometric studies, describing for Astypalea three new species of *Limonium*: *Limonium astypaleanum*, *Limonium contractum*, *Limonium pusillum*. Strid (2016: Part 1, Fig. 2) reported 578 species from Astypalea.

Fig. 2. *Symphytum creticum.*

Material and methods

The floristic data presented in this article came from collections and field observation made by authors on Astypalea at two different periods: August 2015 and April 2016. The field investigations lasted 18 days in August and four days in April. In August 2015, two daily excursions were also undertaken to the islands of Kounoupi and Koutsomytis, and one to the island of Ofidoussa. The collected specimens are deposited in the author's herbarium: Cattaneo (herb. Cattaneo-ASTY). The determination of plant material relied mainly on Rechinger (1943, 1949), Rechinger & Rechinger (1951), Davis (1965–1988), Tutin & al. (1964–1980, 1993), Pignatti (1982), Strid & Tan (1997, 2002), Lafranchis & Sfikas (2009), Dimopoulos & al. (2013), Brullo & Erben (2016), Strid (2016). For the taxonomic-nomenclatural definition of the taxa, Greuter & al. (1984–1989) and Strid (2016) were applied. The division and denomination of the families and the information regarding the distribution of species on Astypalea comply with Strid (2016). The status of endemic taxa recorded for Astypalea and neighboring islands was based on Dimopoulos & al. (2013) (Table 1). Updates relating to the distribution in the floristic regions of Greek endemics such as *Legousia snogerupii*, and *Nigella doerfleri* were derived from Strid (2016), while for the distribution of Greek endemics such as *Limonium astypaleanum*, *L. contractum*, *L. frederici*, *L. pusillum*, were derived from Brullo & Erben (2016). In the vascular plants inventory, families, genera, and species are arranged in alphabetical order. Life-forms categories follow Raunkiaer (1934), while chorological types are based mainly on information provided by Dimopoulos & al. (2013). Plant species introduced to the island were divided into cultivated (CULT), casual (CAS), naturalized (NAT), and invasive (INV). For detecting altitude and geographical coordinates a Garmin GPS III Plus satellite tracking device was used. The name of local places mentioned in the text follow the map of Astypalea produced by Terrain Cartography Group (2009).

Results

The landscape of Astypalea

The landscape of Astypalea is currently deeply degraded, due to heaving and repeated human impact since

ancient times. In the past, the island was rich in forests, which were decimated by humans over the centuries, both for fuel and for the use in farmland and pastures (Theodosopoulos 2005). The eastern part of the island had more than a hundred lime kilns in historical times, used to transform limestone into lime, using the island's trees and shrubs as fuel. Lime production played an important role in the economy of the island, since many islands of the Dodecanese were provided by Astypalea with this material (Theodosopoulos 2005). Over the centuries, this led to a considerable use of firewood to feed these lime kilns, inevitably causing a radical change in the island's landscape. This factor is of fundamental importance for understanding the present landscape of Astypalea. However, overgrazing also played its critical role. On Astypalea, there are currently 15 000 head of livestock: sheep and goat (Elias Skoyfalos, pers. com.). The cattle stays in the same areas throughout the year, causing extensive degradation of the land. The grazing system is actually anachronistic. Most of the land used for grazing shows problems of leaching and erosion, and is often sterile. Schemes have been implemented to improve grassland management, such as the installation of cisterns in several sites on the island and nearby islets like Kounoupi, Koutsomytis, Ofidoussa. This led to improved livestock mobility, but much more needs to be done to improve the current situation.

Ofidoussa

The island of Ofidoussa is located west of Astypalea. It has a maximum height of 133 m and the following geographical coordinates: 36°33'25.05"N, 26°08'28.82"E. The island, which has no bays and a coastline of very high, steep cliffs, is narrow, elongated and without reliefs. It is essentially calcareous and probably has a more ancient origin than Astypalea (Triantis & al. 2008). Ofidoussa is uninhabited, but was used in the past for grazing goats, with some animals still residing in the wild. The vegetation is phryganic and the most representative species are *Sarcopoterium spinosum*, *Pistacia lentiscus* (with reptant and pulvinate habitus) and *Thymbra capitata*. Cliffs are rich in chasmophytic species and in this respect the authors report the presence of *Staehelina fruticosa*. The species has been observed on the eastern side of Ofidoussa, on limestone cliffs characterized by extreme verticality (Cattaneo 2016). Lastly, the presence of the endemic *Limonium frederici* (Brullo & Erben 2016; Strid 2016) is reported.

Kounoupi and Koutsomytis

These small uninhabited islands are located east of Astypalea, off the port of Analipsi/Maltezana. Both Kounoupi and Koutsomytis have a more recent origin, probably Holocene (Triantis & al. 2008). They consist mainly of limestone, with only Koutsomytis showing a good sedimentary component. They are rather flat, with modest reliefs. The vegetation is almost phryganic and the most representative species are *Pistacia lentiscus* and *Juniperus phoenicea*. To a lesser extent there are taxa such as *Thymbra capitata*, *Sarcopoterium spinosum*, *Calicotome villosa*, *Teucrium polium* subsp. *Capitatum,* and *Rhamnus lycioides* subsp. *oleoides*. The chasmophytic species of *Lactuca acanthifolia*, *Scrophularia heterophylla*, *Centaurea raphanina* subsp. *mixta* were observed on Kounoupi's limestone cliffs. *Capparis spinosa* and *Crithmum maritimum* were observed on Koutsomytis, and on the northwestern slope of this island *Erica manipuliflora* becomes part of the phryganic community.

Flora and endemic taxa

The aim of this paper is to make a new contribution to the knowledge of the vascular flora of Astypalea, since 26 new taxa are reported on the island for the first time. On the basis of Greek endemics of the island reported in literature so far, we sought to outline the phytogeographical position of the island. The current landscape of Astypalea (at least the Mesa Nisi) has not changed since the early 1900s, when Béguinot and Vaccari (1912) undertook floristic surveys there. The two authors visited the eastern half of Astypalea, observing only a low maquis, whose characteristic elements were *Juniperus phoenicea*, *Pistacia lentiscus* and *Euphorbia dendroides*. Currently, the landscape is unchanged, at least in the eastern half. Astypalea is characterized by two kinds of floristic composition: phrygana, consisting mainly of S*arcopoterium spinosum*, *Thymbra capitata*, *Salvia fruticosa*, *Genista acanthoclada*, and *Calicotome villosa*, developing chiefly in the western half of the island (Exo Nisi); a low maquis of *Juniperus phoenicea* and *Pistacia lentiscus*, growing almost exclusively in the eastern half of the island (Mesa Nisi), and in a small southeastern area of the Exo Nisi. The island has virtually no tree vegetation.

Astypalea has degraded over the centuries but the presence of limestone cliffs has allowed some rare and endemic species (most of them with restricted range)

to become established, revealing interesting phytogeographic connections between Astypalea and the three floristic regions Kik, KK and EAe (Strid & Tan 1997) (Table 1). Astypalea, like most of the most isolated islands of the south Aegean, is characterized by a good degree of endemism, probably due to the remarkable isolation that has characterized these islands and to discrete environmental heterogeneity at topographical and geological level (Panitsa & al. 2010). Analyzing Aegean endemics in Astypalea, which falls within the floristic region of the Kiklades, it is seen that despite its bridging position with the Dodecanese, there seems to be more floristic affinities with the phytogeographic area of Crete and Karpathos (KK), than with the East Aegean Islands (EAe). Astypalea hosts 33 Cycladic endemics (Table 1). Among these, 23 are also present in KK and 15 in the EAe. The endemics belong to 15 families and to 26 genera. The families with a higher degree of endemism are *Asteraceae*, *Caryophyllaceae* and *Plumbaginaceae*. The Cycladic phytogeographic area is chorologically closer to the EAe (East Aegean Islands) than to KK (Crete and Karpathos) (Georghiou & Delipetrou 2010). However, detection on Astypalea of endemics otherwise present exclusively on Kik and KK, like *Eryngium amorginum*, *Symphytum creticum* (Fig. 2), *Alyssoides cretica*, *Campanula laciniata*, *Dianthus cinnamomeus*, *Dianthus fruticosus* subsp. *amorginus*, *Ornithogalum creticum*, and *Limonium frederici* (Ofidoussa), shows the strong phytogeographic connection between the two floris-

Table 1. Greek endemic taxa occurring on Astypalea and nearby islets (data extrapolated from Dimopoulos & al. 2013, Brullo & Erben 2016 and Strid 2016).

Family	Taxon	IoI	NPi	SPi	Pe	StE	EC	NC	NE	NAe	WAe	Kik	KK	EAe
Alliaceae	*Allium brulloi*											*		
	Allium pilosum											*		*
Apiaceae	*Eryngium amorginum*											*	*	
	Pimpinella pretenderis											*		
Asteraceae	*Anthemis scopulorum*				*							*	*	*
	Carthamus leucocaulos				*						*	*	*	*
	Centaurea raphanina				*	*					*	*	*	*
	Echinops graecus				*	*	*				*	*		
	Filago aegaea subsp. *aegaea*											*	*	*
	Filago cretensis				*					*	*	*	*	*
	Scorzonera araneosa											*		
	Staehelina fruticosa											*	*	*
Boraginaceae	*Symphytum creticum*				*							*	*	
Brassicaceae	*Alyssoides cretica*											*	*	
	Fibigia lunarioides											*	*	*
Campanulaceae	*Campanula laciniata*											*	*	
	Legousia snogerupii											*		
Caryophyllaceae	*Arenaria aegaea*				*							*	*	*
	Dianthus cinnamomeus											*	*	
	Dianthus fruticosus subsp. *amorginus*											*	*	
	Silene sartorii				*	*						*	*	
Chenopodiaceae	*Caroxylon aegaeum*				*	*						*	*	*
Fabaceae	*Ononis spinosa* subsp. *diacantha*	*			*		*					*	*	*
Hyacinthaceae	*Ornithogalum creticum*											*	*	
Iridaceae	*Crocus cartwrightianus*				*	*					*	*	*	*
	Crocus tournefortii				*							*	*	*
Lamiaceae	*Origanum calcaratum*											*	*	*
Orchidaceae	*Ophrys fuciflora* subsp.*andria*											*		
Plumbaginaceae	*Limonium astypaleanum*											*		
	Limonium contractum											*		
	Limonium frederici											*	*	
	Limonium pusillum											*		
Ranunculaceae	*Nigella doerfleri*				*							*	*	*

tic regions. This floristic affinity could possibly be related to the palaeogeographical closeness between the Kiklades, Crete and Karpathos during the Messinian salinity crisis (Kougioumoutzis & al. 2014).

Phytogeographic connections

There has been much debate about the biogeographical position of Astypalea and its relationship with the Kiklades and the East Aegean Island (Sfenthourakis 1996). Current data confirm that although Astypalea is influenced by the abovementioned archipelagos, the Cycladic element is more noticeable. This is demonstrated clearly by data related to terrestrial malacofauna (Triantis & al. 2008), herpetofauna – the Balkan endemic species *Podarcis erhardii* which has mainly Cycladic and continental distribution, is present on the island (Valakos & al. 2008), and also by data regarding the flora, which includes a high number of endemic species of Cycladic origin.

The geological history of Astypalea remains unclear. The island was still joined to the rest of the Kiklades during the Upper Miocene (Creutzburg 1963; Dermitzakis & Papanikolaou 1981; Dermitzakis 1990). During the Middle Miocene, the Cycladic plateau seems to have separated from the eastern islands (Sfenthourakis 1996) and was later subject to further episodes of reconnection and separation. It is likely, therefore that Astypalea also detached from the rest of the Cycladic plateau between the Middle Miocene and the Pliocene. This relatively recent detachment would explain the strong Cycladic element present on the island. During their geological history, most of the Aegean islands suffered reconnections and separations, especially during the Pleistocene, due to tectonic and eustatic movements and fluctuations in sea level caused by glaciations (Sfenthourakis 1996). Of great relevance was the regression of the Aegean Sea during the Messinian, a process that reversed itself only after 1100 years (Cattaneo 2010; Lymberakis & Poulakakis 2010). This led to a migration and different distribution of animal and plant species in the Aegean area. Therefore, it is plausible that the bridge created between Crete and Karpathos, and the rest of the Kiklades, brought about a northward migration of southern floristic elements. This would explain the strong floristic affinities of Astypalea with Crete and Karpathos (KK). Moreover, the existence of bi-regional endemics is a good indication of phytogeographical connection between the two floristic regions (Georghiou & Delipetrou 2010), and was widely debated and documented by Kougioumoutzis (2012, 2014), analyzing the flora of Anafi and Kimolos. Astypalea is home to many rare taxa (Phitos & al. 2009), some of which with a restricted range (Dimopoulos & al. 2013). Given its remarkable floristic and phytogeographic features, it seems appropriate to propose a species list of great ecological interest for the island:

Allium brulloi Salmeri. A species endemic to Astypalea and the islet of Kounoupi. This species grows in the crevices of limestone rocks with other rare chasmophytic species (Salmeri 1998).

Allium pilosum Sm. A rare Greek endemic originally reported only for Kimolos island (Sibthorp & Smith 1809). Later on it was also found in other islands such as Naxos, Astypalea (Dumont d'Urville 1822), Milos (Halácsy 1904), and Psarà (Kollmann 1984). Currently, it has also been reported on the small island of Pontikoussa, northwest of Astypalea (Sfikas & Tan 2013).

Eryngium amorginum Rech. f. A distinctive endemic of the southeast Aegean area with a very restricted range. It occurs in Astypalea and also in sites on Amorgos island; rare elsewhere. This chasmophytic species grows in the crevices of north-facing limestone cliffs, often windswept. Since the distribution range of *Eryngium amorginum* is similar to that of *Seseli crithmifolium* and *Senecio bicolor*, which appear to be Pliocene relicts, the same could also be said for the species in question. It is the only chasmophytic species in the *genus Eryngium* (Wörz 2006).

Pimpinella pretenderis (Heldr.) Halácsy. A Cycladic endemic with a restricted range. In Astypalea, it has been found only on the east coast and in some nearby islets (Strid 2016).

Anthemis scopulorum Rech. f. A Greek endemic and "islet specialist". *Anthemis scopulorum* is a very polymorphic taxon and the remarkable local differences are probably the result of isolation of the populations on each island (Georgiou & al. 2006). This species is present on Astypalea as *Anthemis scopulorum* var. *ofidoussa*. It was found in its *locus classicus* in the small island of Ofidoussa, located west of Astypalea and in an isolated place in the east side of Astypalea. It was also found in the northern part of Antikythera, where it is in sympatry with *Anthemis scopulorum* var. *scopulorum* (Georgiou 1990).

Centaurea raphanina Sm. subsp. ***mixta*** (DC.) Runemark. Runemark (1967) dealt in detail with the *Centaurea raphanina* complex, distinguishing the subspecies *Centaurea raphanina* subsp. *raphanina*, with a range restricted to Crete and Karpathos, and *Centaurea raphanina* subsp. *mixta*, with a range including the Kiklades and the mainland (Runemark 1967). In some central Cycladic islands (Strid 2016), intermediate individuals between the two subspecies were detected. In Astypalea specimens with features belonging to both these subspecies were observed: specimens with hairless, glossy, petiolate leaves, pink, rounded *capitula*, rather long (5–25 mm) petiolate and apical spines, features that refer to the subspecies *mixta*; specimens with hairy and matt leaves on the basal rosette, with little or no petiole, pink and elongated *capitula*, apical spines shorter than the previous type (3–10 mm), features that refer to the subspecies *raphanina*. *Centaurea raphanina* subsp. *mixta* (Strid 2016) is reported on Astypalea, but it is likely that in addition to the above subspecies, there are specimens with intermediate characteristics between the two subspecies. A finding is reported on a vertical limestone cliff of Koutela Mountain, at 380 m a.s.l. (36°31'33.96"N, 26°19'10.28"E), of two specimens presumably belonging to subsp. *mixta*, showing yellow and not pink flowers, the latter being the typical color of that species (Fig. 3). Presumably, this chromatic variation falls within the variability inherent to the *Centaurea raphanina* complex.

Staehelina fruticosa (L.) L. A southeast Greek endemic and obligated chasmophytic species, with remarkable woodiness, growing on limestone cliffs with strong verticality. It also occurs in Crete and Karpathos and in some central Cycladic islands. On Astypalea, it was observed by the authors only on vertical limestone cliffs which form the gorge of Vatses bay (Fig. 4). It is recorded for the first time for the island of Ofidoussa, where it was observed on limestone cliffs on the eastern side of the island (Cattaneo 2016).

Campanula laciniata L. A rather rare Greek endemic with a range restricted to Crete, Karpathos and some Cycladic islands. On Astypalea, it was observed on the massifs of Ftera and Koutela, in limestone cliff crevices (Fig. 5).

Legousia snogerupii Biel & Tan. A recently described species (Tan & al. 2015), with features very similar to *Legousia speculum-veneris* and particularly to *Legousia pentagonia*. It is found in the western half of Astypalea, as well as on Ofidoussa, Syrna, Amorgos and Levitha.

Dianthus cinnamomeus Sm. An Aegean endemic with a very restricted range, found not only on Astypalea, but also on a few Cycladic islands, including Amorgos, Iraklia and Naxos (where the subspecies *Dianthus cinnamomeus* subsp. *naxensis* is present), and in the south Aegean only on Kasos island. This is a chasmophytic species which grows both on flysch and limestone.

Dianthus fruticosus L. subsp. ***amorginus*** Runemark. One of the allopatric species living in the Aegean area, it is an obligated chasmophytic species with remarkable woodiness, growing on limestone cliffs.

Fig. 3. *Centaurea raphanina* subsp. *mixta.*

Fig. 4. *Staehelina fruticosa.*

Fig. 5. *Campanula laciniata.*

Nigella doerfleri Vierh. An endemic species with a range restricted to Kik and KK (Fig. 6). It occurs on Astypalea and was also recently reported on Tilos (Dodecanese), expanding its distribution area in the EAe (Strid 2016).

Finally, we would draw attention to a species wrongly reported for Astypalea: *Bongardia chrysogonum*. In actual fact, d'Urville found *Leontice leontopetalum* on Astypalea. Later Boissier (1867: 99) inexplicably replaced the name of the species discovered by d'Urville, with *Bongardia chrysogonum*. The reporting of *Bongardia chrysogonum* for Astypalea is to be considered a mistake in the light of current studies (Karl & Strid 2009). The mistake was replicated in subsequent *Floras*. Only a detailed study of the specimen collected by d'Urville and deposited in the Paris Herbarium clarified that it was *Leontice leontopetalum*.

Fig. 6. *Nigella doerfleri.*

Vascular plant inventory of Astypalea, Ofidoussa, Kounoupi, and Koutsomytis

The species detected on the nearby islets of Ofidoussa, Kounoupi and Koutsomytis are indicated by the respective abbreviations: **Ofid** = Ofidoussa, **Koun** = Kounoupi, **Kout** = Koutsomytis. Other abbreviations used are: **CULT** – cultivated, **CAS** – casual, **NAT** – naturalized, **INV** – invasive; **P** – phanerophyte, **NP** – nanophyte, **Ch** – chamaephyte, **H** – hemicryptophyte, **G** – geophyte, **T** – therophyte. Chorological types follow Dimopoulos & al. (2013).
New records are marked by an asterisk *.

PTERIDOPHYTAE

Aspleniaceae
Asplenium ceterach L. - H ros - EA

Pteridaceae
Adiantum capillus-veneris L. - G rhiz - ST
Cheilanthes acrostica (Balb.) Tod. - G rhiz - Me

GYMNOSPERMAE

Cupressaceae
Cupressus sempervirens L. - P scap - CULT
Juniperus phoenicea L. - P scap - Me - Koun - Kout

Ephedraceae
Ephedra foeminea Forssk. - NP - Me

Pinaceae
Pinus pinea L. - P scap - CULT

ANGIOSPERMAE

Acanthaceae
Acanthus spinosus L. - H scap - Me

Aizoaceae
**Carpobrotus edulis* (L.) N. E. Br. - Ch suffr - CAS
Mesembryanthemum nodiflorum L. - T scap - CAS

Alliaceae
Allium ampeloprasum L. - G bulb - Me
Allium bourgeaui Rech. f. subsp. *Cycladicum* Bothmer - G bulb -EM
Allium subhirsutum L. - G bulb - Me

Anacardiaceae
Pistacia lentiscus L. - P scap - Me - Koun - Kout - Ofid

Schinus molle L. - P scap - CULT

Apiaceae
Cachrys cristata DC. - H scap - Me
Crithmum maritimum L. - Ch suffr - ME - Koun - Kout - Ofid
Daucus carota L. - T scap - Pt
Eryngium campestre L. - H scap - EA
**Foeniculum vulgare* Mill. - H scap - Me
Hellenocarum multiflorum (Sm.) H. Wolff - H scap - Me
Lagoecia cuminoides L. - T scap - ME
Scandix pecten-veneris L. - T scap - EA
**Smyrnium perfoliatum* L. - H bienn - ME
Thapsia garganica L. - H scap - Me
Tordylium aegaeum Runemark - T scap - EM
Tordylium apulum L. - T scap - Me

Apocynaceae
Nerium oleander L. - P caesp - Me

Araceae
Arisarum vulgare O. Targ. Tozz. - G rhiz - Me
Dracunculus vulgaris Schott - G rhiz - Me

Arecaceae
Phoenix canariensis Chabaud - P scap - CULT

Asparagaceae
Asparagus acutifolius L. - Ch frut - Me (species observed exclusively on Koutsomytis)
Asparagus aphyllus L. - Ch frut - Me
Asparagus horridus L. - Ch frut - Me

Asphodelaceae
**Asphodelus fistulosus* L. - G rhiz - Me
Asphodelus ramosus L. - G rhiz - Me

Asteraceae
Anthemis chia L. - T scap - Me
Calendula arvensis L. - T scap - ME
Carduus pycnocephalus L. - H bienn - ME
Carlina corymbosa L. subsp. *graeca* (Heldr. & Sartori) Nyman - H scap - BA - Koun
**Carthamus dentatus* (Forssk.) Vahl - T scap - Me
Carthamus lanatus L. - T scap - Me
Centaurea raphanina Sm. subsp. *mixta* (DC.) Runemark - H ros - Endem.
Cichorium intybus L. - H scap - EA
Cichorium spinosum L. - Ch suffr - Me
Crupina crupinastrum (Moris) Vis. - T scap - EA
Cynara cornigera Lindl. - H scap - EM
Echinops spinosissimus Turra - H scap - Me - Kout
**Erigeron canadensis* L. - T scap - NAT
Filago pyramidata L. - T scap - Me
Glebionis coronaria (L.) Spach - T scap - Me
Glebionis segetum (L.) Fourr. - T scap - Me
Helichrysum orientale (L.) Vaill. - H scap - EM
Helichrysum stoechas (L.) Moench - Ch suffr - Me
**Helminthotheca echioides* (L.) Holub - T scap - Me
Inula graveolens (L.) Desf. - T scap - Me
Inula viscosa (L.) Aiton - T scap - Me
Lactuca acanthifolia (Willd.) Boiss. - Ch scap - EM - Koun
Lactuca serriola L. - H scap - Pt
**Lactuca viminea* (L.) J. Presl & C. Presl - H bienn - Pt
Notobasis syriaca (L.) Cass. - T scap - Me
Onopordum tauricum Willd. - H bienn - ME
Pallenis spinosa (L.) Cass. - H bienn - Me
Phagnalon rupestre (L.) DC. subsp. *graecum* (Boiss. & Heldr.) Batt. - Ch suffr - Me
Picnomon acarna (L.) Cass. - H scap - Pt
Ptilostemon chamaepeuce (L.) Less. - Ch frut - EM
Reichardia picroides (L.) Roth - T scap - Me
Scolymus hispanicus L. - H bienn - ME
**Silybum marianum* (L.) Gaertn. - T scap - Me
**Sonchus asper* (L.) Hill - T scap - Pt
Staehelina fruticosa (L.) L. - Ch suffr - Endem. - Ofid
Tragopogon porrifolius L. - H bienn - Me
Urospermum picroides (L.) F. W. Schmidt - T scap - Me

Boraginaceae
Anchusa aegyptiaca (L.) A. DC. - T ros - EM
Anchusa azurea Mill. - H scap - Me
Cynoglossum creticum Mill. - H bienn - EA
Echium arenarium Guss. - H bienn - Me
Echium plantagineum L. - H bienn - ME
Heliotropium hirsutissimum Grauer - T scap - EM
Onosma graeca Boiss. - H scap - EM
Symphytum creticum (Willd.) Runemark ex Greuter & Rech. f. - H scap - Endem.

Brassicaceae
Alyssoides cretica (L.) Medik - Ch frut - Endem.
Cakile maritima Scop. - T scap - ME
Fibigia lunarioides (Willd.) Sweet - Ch suffr - Endem.
Hirschfeldia incana (L.) Lagr.-Foss. - T scap - EA
Raphanus raphanistrum L. - T scap - EA/Co

Cactaceae
**Opuntia ficus-indica* (L.) Mill. - P succ - Neotrop.

Caesalpiniaceae
Ceratonia siliqua L. - P scap - Me

Campanulaceae
Campanula erinus L. - T scap - ME
Campanula laciniata L. - H bienn - Endem.
Legousia pentagonia (L.) Druce - T scap - EM

Capparaceae
Capparis spinosa L. subsp. *rupestris* (Sm.) Nyman - NP - Me - Koun - Kout - Ofid

Caprifoliaceae
Lonicera etrusca Santi - P caesp - Me

Caryophyllaceae
Dianthus cinnamomeus Sm. - H caesp - Endem.
Dianthus fruticosus L. subsp. *amorginus* Runemark - Ch suffr - Endem.
Paronychia macrosepala Boiss. - H caesp - EM

Chenopodiaceae
Atriplex halimus L. - P caesp - MS
Beta vulgaris L. - H scap - EA
Chenopodiastrum murale (L.) S. Fuentes & al. - T scap - EA
Salsola kali s. lat. L. - T scap - Pt

Cistaceae
Cistus parviflorus Lam. - NP - EM
Fumana arabica (L.) Spach - Ch suffr -Me

Convolvulaceae
Convolvulus althaeoides L. - H scand - Me
Convolvulus arvensis L. - G rhiz - Co
Convolvulus dorycnium L. - Ch suffr - Me
Convolvulus elegantissimus Mill. - H scand - Me
Convolvulus oleifolius Desr. - Ch frut - Me
Cuscuta palaestina Boiss. - T par - Me

Crassulaceae
Sedum litoreum Guss. - T scap - Me
Umbilicus horizontalis (Guss.) DC. - G bulb - Me

Cucurbitaceae
Bryonia cretica L. - G rhiz - EM
**Ecballium elaterium* (L.) A. Rich. - G bulb - MS

Cyperaceae
Schoenus nigricans L. - H caesp - Co
Scirpoides holoschoenus (L.) Soják - G rhiz - Pt

Ericaceae
Erica manipuliflora Salisb. - Ch suffr - Me - Kout

Euphorbiaceae
Euphorbia acanthothamnos Heldr. & Sart. ex Boiss. - Ch suffr - EM
Euphorbia dendroides L. - P caesp - Me
Euphorbia peplis L. - T scap - ME

Fabaceae
Anagyris foetida L. - P scap - Me
Bituminaria bituminosa (L.) C. H. Stirt. - H scap - ME
Calicotome villosa (Poir.) Link - P caesp - Me - Koun
Genista acanthoclada DC. - P caesp - EM
Lotus cytisoides L. - Ch suffr - Me
Lotus ornithopodioides L. - T scap - Me
**Medicago arborea* L. - P caesp - Me
Medicago disciformis DC. - T scap - Me
Ononis spinosa L. subsp. *diacantha* (Rchb.) Greuter - Ch suffr - Endem.
**Spartium junceum* L. - P caesp - Me
**Trifolium subterraneum* L. - T rept - ME
Tripodion tetraphyllum (L.) Fourr. - T scap - Me

Fagaceae
**Quercus ithaburensis* Decne. subsp. *macrolepis* (Kotschy) Hedge & Yalt. - P scap - Me

Frankeniaceae
Frankenia hirsuta L. - Ch suffr - MS

Fumariaceae
Fumaria judaica Boiss. - T scap - EM
Fumaria macrocarpa Parl. - T scap - Me

Geraniaceae
Erodium malacoides (L.) L'Hér. - H bienn - MS
Geranium purpureum Vill. - T scap - Me

Hyacinthaceae
Drimia maritima (L.) Stearn, s. lat. - G bulb - Me - Koun - Kout - Ofid
Muscari comosum (L.) Mill. - G bulb - ME
Ornithogalum creticum Zahar. - G bulb - Endem.
Ornithogalum narbonense L. - G bulb - Me

Hypericaceae
**Hypericum perforatum* L. - H scap - Pt
Hypericum triquetrifolium Turra - H scap - MS

Iridaceae
Gladiolus italicus Mill. - G bulb - MS
Iris germanica L. - G bulb - EA

Juncaceae
Juncus heldreichianus T. Marsson ex Parl. - H scap - EM

Lamiaceae
Ballota acetabulosa (L.) Benth. - Ch frut - BA - Koun - Kout
Origanum onites L. - Ch suffr - Me
Prasium majus L. - Ch frut - Me
Salvia fruticosa Mill. - Ch frut - EM
Satureja thymbra L. - Ch frut - Me
Teucrium brevifolium Schreb. - Ch suffr - Me
Teucrium divaricatum Heldr. - Ch suffr - EM
Teucrium polium L. subsp. *capitatum* (L.) Arcang. - Ch suffr - Me - Kout
Thymbra capitata (L.) Cav. - Ch suffr - Me - Koun - Kout - Ofid

Liliaceae
Gagea graeca (L.) Irmsch. - G bulb - BA

Linaceae
Linum strictum L. - T scap - Me

Malvaceae
Malva cretica Cav. - T scap - Me
**Malva multiflora* (Cav.) Soldano & al. - T scap - Me
Malva nicaeensis All. - T scap - Me
Malva sylvestris L. - H scap - EA

Meliaceae
Melia azedarach L. - P scap - CULT

Mimosaceae
Acacia saligna (Labill.) H. L. Wendl. - P scap - CAS

Moraceae
Ficus carica L. - P scap - CULT

Myrtaceae
Eucaliptus camaldulensis Dehnh. - P scap - CULT
Myrtus communis L. - P scap - Me

Oleaceae
Olea europaea L. - P scap - CULT

Orchidaceae
Anacamptis pyramidalis (L.) Rich. - G bulb - Eu
Ophrys ferrum-equinum Desf. - G bulb - BA

Orobanchaceae
Orobanche pubescens d'Urv. - T scap - Me
Phelipanche mutelii (F. W. Schultz) Pomel - T scap - Pt

Oxalidaceae
Oxalis pes-caprae L. - G bulb - Neotrop.

Papaveraceae
Glaucium flavum Crantz - H scap - ME
Papaver hybridum L. - T scap - EA
Papaver nigrotinctum Fedde - T scap - BA
Papaver rhoeas L. - T scap - Pt

Platanaceae
Platanus orientalis L. - P scap - EM

Plumbaginaceae
Limonium astypaleanum Erben & Brullo - Ch suffr - Endem.
Limonium virgatum (Willd.) Fourr. - Ch suffr - Me

Poaceae
Aeluropus littoralis (Gouan) Parl. - G rhiz - MS - Kout
Aira elegans Willd. ex Roem. & Schult. - T scap - MS
Avena sterilis L. - T scap - MS - Koun - Kout
Arundo donax L. - P scap - Co
**Bromus hordeaceus* L. - T scap - Co
Bromus madritensis L. - T scap - MS
Cynodon dactylon (L.) Pers. - G rhiz - Co
Dactylis glomerata L. - H scap - Pt
Elytrigia sartorii (Boiss. & Heldr.) Holub - H scap - EM
Hordeum murinum L. - T scap - MS

Hyparrhenia hirta (L.) Stapf - H caesp - ST - Koun - Kout
Lagurus ovatus L. - T scap - Me - Kout - Ofid
Melica minuta L. - H scap - Me
**Paspalum dilatatum* Poir. - H scap - Neotrop.
Polypogon monspeliensis (L.) Desf. - T scap - ST
Rostraria cristata (L.) Tzvelev - T scap - Co - Ofid
**Sorghum halepense* (L.) Pers. - G rhiz - Co

Polygonaceae
Rumex bucephalophorus L. - T scap - Me
Rumex pulcher L. - H scap - MS
Rumex tuberosus L. - G bulb - MS

Portulacaceae
Portulaca oleracea L. aggr. - T scap - Co

Posidoniaceae
Posidonia oceanica (L.) Delile - I rad - Me - Koun - Kout

Primulaceae
Samolus valerandi L. - H scap - Co

Punicaceae
**Punica granatum* L. - P scap - CULT

Ranunculaceae
Nigella doerfleri Vierh. - T scap - Endem.

Resedaceae
Reseda lutea L. - H bienn - Pt

Rhamnaceae
Rhamnus lycioides L. subsp. *oleoides* (L.) Jahand. & Maire - P caesp - Me - Koun

Rosaceae
Pyrus spinosa Forssk. - P scap - Me
Sarcopoterium spinosum (L.) Spach - NP - EM - Koun - Kout - Ofid

Rubiaceae
Crucianella latifolia L. - T scap - ME
Galium setaceum Lam. - T scap - MS
Rubia tenuifolia d'Urv. - P lian - EM
Valantia muralis L. - T scap - Me - Kout

Rutaceae
**Ruta chalepensis* L. - Ch suffr - Me

Santalaceae
Osyris alba L. - P scap - Me
Thesium humile Vahl - T scap - Me

Scrophulariaceae
Scrophularia heterophylla Willd. - H scap - EM - Koun
Verbascum sinuatum L. - H bienn - MS

Solanaceae
Hyoscyamus albus L. - H bienn - Me
Mandragora officinarum L. - H ros - Me
Solanum nigrum L. - T scap - CAS

Tamaricaceae
**Tamarix parviflora* DC. - P scap - MS

Typhaceae
**Typha domingensis* Pers. - G rhiz - ST

Urticaceae
Parietaria cretica L. - T rept - EM
Parietaria judaica L. - H scap - EA
Parietaria lusitanica L. - T scap - ME
Urtica pilulifera L. - T scap - MS

Valerianaceae
Centranthus calcitrapae (L.) Dufr. - T scap - Me

Verbenaceae
Vitex agnus-castus L. - P caesp - MS

Veronicaceae
**Antirrhinum majus* L. - Ch frut - WM
Kickxia elatine (L.) Dumort. - T rept - EA

Zygophyllaceae
Tribulus terrestris L. - T rept - Co

Conclusions

Astypalea appears as a rather degraded island, attributable to the poor human management of its plant heritage. Negative anthropic impact had continued for centuries, both through the use of tree and shrub cover to feed lime kilns, and through intense over-grazing, causing problems of leaching and soil erosion, making the island almost completely sterile. Currently, the natural richness of this island lies in the presence of elective habitats for avifauna and for some animal and plant species of particular interest. The latter are chasmophytic species, endemic to the Aegean district, which in most cases are also rare, often characterized by quite restricted distribution areas. This floristic richness is closely related to the presence of limestone cliffs both in the western and in the eastern halves of Astypalea, confirming the remarkable correlation between chasmophytism and endemism (Kypriotakis & Tzanoudakis 2001; Cattaneo & Grano 2016). There are many rare and endemic species reported for the island. The endemic *Allium brulloi* is exclusive to Astypalea and the small island of Kounoupi. *Limonium astypaleanum*, *L. contractum* and *L. pusillum* are endemics of Astypalea (Brullo & Erben 2016), and there are species with a very restricted range such as *Allium pilosum* and *Ophrys fuciflora* subsp. *andria*. There is a punctiform distribution of rare taxa on Astypalea, including *Anthemis scopulorum*, found in an isolated site in the eastern part of the island, and *Staehelina fruticosa*, occurring only in Vatses bay (southwest). This indicates that these species are highly specialized and closely related to specific biotopes characterized by specific climatic and soil factors (Davis 1951). Many chasmophytic plants of particular interest have been found in deep gorges, characterized by north-facing limestone vertical cliffs, such as Vatses and Kaminakia (southwest). It is plausible that these gorges, being less subject to climatic variations, favored the establishment of some species, providing them with a more stable habitat. Despite the

two aforementioned gorges having similar characteristics, both being deep gorges formed by Eocene limestone (Leontaris 1973), adjacent and parallel to each other, the distribution of chasmophytic flora differs. For example, the rare endemic *Staehelina fruticosa* was observed only on north-facing cliffs in Vatses bay, at 300 m a.s.l. Factors such as insularity, hilliness (Georghiou & Delipetrou 2010), isolation, and environmental heterogeneity (Panitsa & al. 2010) foster the existence of a good degree of endemism and Astypalea has all these requirements. The study of endemic taxa on the island has allowed definition of the phytogeographic position of Astypalea, showing a greater connection between Kiklades (Kik) and the southern Aegean (KK), rather than with the East Aegean Islands (EAe). On Astypalea, the occurrence of bi-regional endemics like *Eryngium amorginum*, *Symphytum creticum*, *Alyssoides cretica*, *Campanula laciniata*, *Dianthus cinnamomeus*, *Dianthus fruticosus* subsp. *amorginus*, *Silene sartorii*, *Ornithogalum creticum*, and *Limonium frederici*, occurring exclusively in Kik and KK, shows more floristic affinities with KK rather than with the EAe. This is probably related to the paleogeographic proximity of the southern Aegean, which occurred during the Messinian salinity crisis. However, these floristic affinities between Kik and KK have already been highlighted for the Cycladic islands of Anafi (Kougioumoutzis 2012) and Kimolos (Kougioumoutzis 2014).

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