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Flora and factors affecting species diversity in the islet groups of the protected “Natura 2000” sites of the Amvrakikos Gulf and Mesolongi Lagoon (Ionian area, Greece)

Abstract

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The vascular plant species diversity of the islet groups in the Amvrakikos Gulf and Mesolongi Lagoon, hitherto unexplored, is documented by an inventory of vascular plants, filling gaps in the floristic information available for the two National Parks to which these islet groups belong, as well as for the Ionian land-bridge island system for which detailed studies concerning floristic and phytogeographical relationships were available before. The total vascular flora of the two islet groups comprises 226 plant taxa. Spectra of life-form and chorological elements are presented and discussed. Floristic cross-correlations (beta-diversity) show that the individual islet floras differ from each other from 39 % to 91 %. Concerning the role of eco-geographical variables as influencing plant species diversity in the area, regression analyses indicate island area as the major predictor variable of species richness.

Additional key words: island biogeography, land-bridge islands, phytogeography, Mediterranean region, vascular plants, beta-diversity

Introduction

Plant species richness and distribution patterns on oceanic versus chersogenous islands have been extensively studied in island biogeography. An important point is to determine factors affecting species richness and repartition on islands. This becomes critical when the islands concerned are protected by law and conservation efforts are claimed.

The ecological importance of the Ionian area from a nature conservation point of view was mentioned by Iliadou & al. (2014). The designation of two national parks and Ramsar Convention sites of international importance for birds on the border of W mainland Greece and the Ionian archipelago makes it important to elucidate the biogeographical relationship of the Ionian area to the adjacent parts of the Greek mainland.

Plant species diversity of some larger Ionian islands and islet groups has been studied already, but there is still a large number of small islands and islets that have not been investigated at all and have remained completely unexplored floristically, such as the islet groups in the marginal seas of the Amvrakikos Gulf and the Mesolongi Lagoon (Fig. 1).

The islet group in the Amvrakikos Gulf belongs to the Natura 2000 Site of Community Importance GR2110001, “Amvrakikos Gulf, Louros and Arachthos Delta”, which also includes the Special Protection Area GR2110004, “Amvrakikos Gulf, Katafourko lagoon and Korakonia”. Both sites belong to the “Amvrakikos Wetlands National Park”. The islet group in the Mesolongi Lagoon is part of two overlapping Natura 2000 sites, a Special Protection Area (GR2310015) and a Site of European

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Community Importance (GR2310001), which compose the “National Park of Mesolongi – Aitoliko lagoons, estuaries of Acheloos and Evinos River and Echinades islet group”. These two national parks are of the most diverse and complex sites of the Natura 2000 ecological network in Greece and also represent two of Greece’s 11 Ramsar Convention wetlands, which are of international importance for the conservation of their avifauna (Dimopoulos & al. 2005).

The floristic composition of the two islet groups under discussion here (Fig. 1) was hitherto unknown, and for this reason the main objectives of the present study are: (1) to provide for the first time a floristic inventory of the protected islet groups, thus continuing current studies of the plant species diversity of the Ionian islets (Iliadou & al. 2014); (2) to investigate the floristic similarities among the individual islets; and (3) to explore the main factors affecting plant species richness in the two islet groups in order to highlight the role of geographical variables in shaping their flora. In the given conservation context, factors determining plant species richness and habitat composition may also directly or indirectly influence animal and especially bird species richness (Kissling & al. 2008).

Material and methods

1. Study area

The survey of the two investigated islet groups covers six islets of the Amvrakikos Gulf and four islets of the Mesolongi Lagoon with areas ranging from 0.41 ha to 65.9 ha, very low elevation ranging from 1 m to 8 m a.s.l. and distance from the nearest mainland coastline ranging from 10 m to 5.7 km (Table 1). The low hilly and coastal slopes are generally gentle. The names of the constituting islets and their geographical data are provided in Fig. 1 and Table 1. The islets are uninhabited, but there are one or two small houses for people working in the fish farms that are the main human activity in the surrounding sea. Grazing has been observed on the larger islets. The Amvrakikos Gulf islets belong to the prefecture of Preveza, except the islet of Kefalos, which belongs to the prefecture of Aitolokarnania as

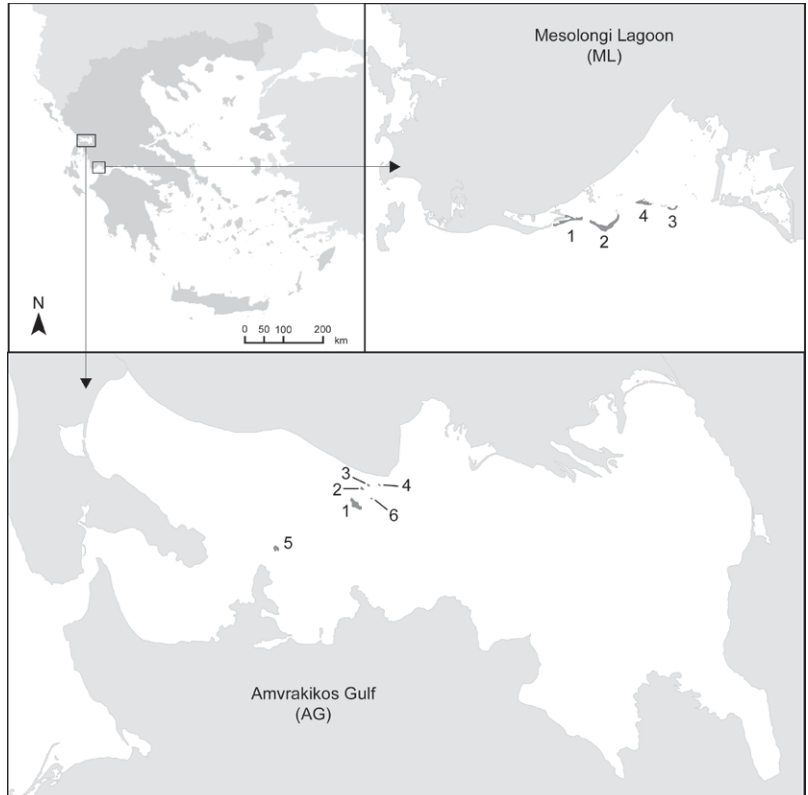


Fig. 1. Map of the two studied islet groups. The numbers correspond to the islet codes in Table 1.

Table 1. Geographical and ecological information about the two studied islet groups. – S = number of taxa; A = surface area [ha]; E = highest elevation [m]; Dm = minimum distance to nearest mainland [km].

Islet name	Islet code	Latitude [N]	Longitude [E]	S	A	E	Dm
Amvrakikos Gulf islets							
Vouvalos	AG1	38°59'11"	20°55'00"	109	13.48	8	1.75
Vlaxos	AG2	38°59'40"	20°55'14"	48	1.36	4	1.05
Diapori	AG3	38°59'45"	20°55'29"	34	0.79	5	0.9
Vouzvara	AG4	38°59'22"	20°55'35"	23	0.41	4	1.7
Kefalos	AG5	38°57'53"	20°52'19"	79	4.3	4	0.95
Agios Antonios	AG6	38°59'58"	20°55'50"	14	0.53	5	0.78
Mesolongi Lagoon islets							
Tholi	ML1	38°18'34"	21°16'17"	113	17.6	3	0.01
Prokopanistos	ML2	38°18'16"	21°18'23"	96	65.9	1	3.16
Agios Sostis	ML3	38°19'14"	21°22'14"	65	8.8	1	3.53
Shinias	ML4	38°19'28"	21°20'33"	56	17.1	1	5.7

also do the islets of the Mesolongi Lagoon. All the islets are owned by the Greek state.

The Amvrakikos Gulf is also a semi-closed sea, watered by plenty of fresh water with sediments. Vött & al. (2007) showed geomorphological, sedimentological and geoarchaeological evidence of multiple tsunami impacts on the Aktio headland (the entrance of the Amvrakikos Gulf). May & al. (2012), studying the Lefkada–Preveza

coastal zone, which is characterized by an active barrier system and related extensive beachrock sequences protecting the entrance to the gulf, concluded that tsunami events in particular have induced sudden impulses of coastal evolution in the study area contributing to coastal and environmental changes involving a recurrent reorganization of the coastal system by gradual, long-term, steadily acting processes such as longshore drift, tending to the establishment of a state of renewed coastal balance. The islets in the Amvrakikos Gulf are composed of Triassic/Lower Jurassic or Jurassic limestones (IGME 1989).

The Mesolongi Lagoon is connected to the Gulf of Patras, which forms a part of the Ionian Sea. The lagoon lies behind a fragmented sandy coastal ridge that separates it from the open sea. It is semi-closed and shallow (the depth ranges from a few cm in the interior regions up to roughly 2.5 m, with a mean depth of approximately 0.5 m) and the circulation is dominated by the tide entering through the Gulf of Patras, at least for ordinary wind conditions (Leftheriotis & al. 2013). The islets in the Mesolongi Lagoon are composed of post-tectonic and late-tectonic sediments of the Holocene (alluvium) in valleys, plains and coastal deposits (IGME 1989). They form a kind of barrier islets (Fig. 1).

Based on the climatic diagram of Emberger (1952), the study area belongs to a subhumid bioclimate characterized by mild winters. The xerothermic index (Bagnouls & Gaussen 1953) and the ombrothermic diagram (UNESCO-FAO 1963) characterize the study area as thermo-Mediterranean with a dry period from early May to mid-October.

Three habitat types of Annex I of the Directive 92/43/EU have been recognized in the study area of the Amvrakikos Gulf islets: vegetated sea cliffs of the Mediterranean coasts (habitat type code 1240), Mediterranean and thermo-Atlantic halophilous scrub (*Sarcocornietea fruticosi*) (1420) and *Olea europaea* – *Pistacia lentiscus* scrub (9320). Five habitat types of Annex I have been recognized on the islets of the Mesolongi Lagoon: habitat type 1420, as in the Amvrakikos Gulf islets, *Salicornia* and other annuals colonizing mud and sand (1310), Mediterranean salt meadows (*Juncetalia maritimi*) (1410), embryonic shifting dunes (2110) and coastal dunes with *Juniperus* species (2250*); plus one more habitat type not included in Annex I: reedbeds (72A0).

2. Annotated floristic inventory

The floristic inventory presented here (see Appendix) includes species and subspecies, with their life-form and chorological categories, of the flora of the individual islets of the two groups. Repeated field trips were carried out between 2007 and 2012 in different seasons of the year, in order to acquire an integrated knowledge of the flora of the islets.

Families, genera, species and subspecies are given in an alphabetic order within the higher groups gymno-

sperms and angiosperms. For simplicity, “taxa” is statistically used hereafter for both species and subspecies (the latter in case a species has more than one subspecies in the area). The plant collections are deposited in Agrinio (W Greece) in the herbarium of the Department of Environmental and Natural Resources Management, Laboratory of Ecology and Nature Conservation.

Nomenclature, life-form and chorological categories follow Dimopoulos & al. (2013) except for *Spergularia marina*, the correct name for *S. salina* (see Buttler & Thieme 2013, the latter designation erroneously accepted in Dimopoulos & al. 2013: 83). For the determination of the plant material, Tutin & al. (1968–1980, 1993), Pignatti (1982) and Strid & Tan (1997, 2002) were used.

3. Floristic similarity analysis

Floristic similarity of the islets per pair (beta-diversity) was calculated using the Sørensen similarity coefficient (Sørensen 1948): $Cs=2j/(a+b)/C$, where j = the number of taxa common to both islets compared, a = the number of taxa recorded from islet 1, and b = the number of taxa recorded from islet 2. In addition, the proportion of islets on which a taxon occurs was calculated. The dendrogram presenting floristic relations between the islets studied (Fig. 2) is based on the hierarchical cluster analysis using Statistica 6 (StatSoft, Inc. 2001).

4. Statistical analysis of the factors affecting plant species richness

Geographical data concerning surface area (A), highest elevation (E) and maximum distance to the nearest mainland (Dm) were determined by open-access digital topographic maps (1:50 000 scale) of the Hellenic Military Geographical Service.

The relationships between plant species richness and the geographical variables affecting it were tested using simple and multiple linear regression analyses and the Spearman correlation coefficient. All regressions and the estimations of parameters were carried out with Statistica 6 (StatSoft, Inc. 2001).

Results

1. Floristic inventory and analysis

There is no previous literature information at all concerning plant species richness of the islets studied. Our pioneer field investigations on all of the ten islets revealed the occurrence of 226 plant taxa.

The vascular plant diversity of the six Amvrakikos Gulf islets comprises 142 plant taxa, belonging to 45 families, 117 genera, 130 species and 12 subspecies, while the vascular plant diversity of the four Mesolongi Lagoon islets comprises 164 plant taxa, belonging to 46 families, 126 genera, 155 species and nine subspe-

cies (Table 2). Except for two gymnosperms, all of the taxa are angiosperms. Vascular cryptogams have not yet been found.

In both island groups a high percentage (c. 43%) of the taxa belongs to three families: *Poaceae* (23 taxa), *Asteraceae* and *Fabaceae* (19 taxa each). Therophytes predominate (52.1%–53%) and Mediterranean plant taxa represent 75.2% of the Amvrakikos Gulf islets flora and 66.7% of the Mesolongi Lagoon islets flora. For the life-form spectrum see Table 3; for the chorological spectrum see Table 4.

Four alien taxa, according to Arianoutsou & al. (2010), are present in the flora of the islets studied, viz.: *Erigeron bonariensis*, *Phalaris canariensis*, *Symphotrichum squamatum* and *Xanthium orientale* subsp. *italicum*.

Eleven of the taxa recorded are included in the IUCN Red List of Threatened Species (IUCN 2013) and three are included in the European Red List of Vascular Plants (Bilz & al. 2011), all of characterized as Least Concern (LC); 27 taxa are included in the list of UNEP (2014) (see Table 5).

2. Floristic similarity among the studied islets

Floristic cross-correlations (beta-diversity) between the studied islets by means of the Sørensen similarity coefficient revealed values (0.09–0.61) showing that the floras of each of the studied islets differ from each other from 39% to 91% (Fig. 2). The hierarchical cluster analysis showed that the island of Vouvalos (AG1), highest and largest of the Amvrakikos Gulf islets group, has a very different floristic composition as also does the medium-sized islet of Kefalos (AG5), when compared to all the other islets (Fig. 2). The other four, smaller Amvrakikos Gulf islets group together, as also do the four Mesolongi Lagoon islets (Fig. 2).

Concerning the number of islets on which each taxon occurs, 33.2% of the taxa occur on only one of the ten studied islets, 23.5% on only two of them and 15.9% on only three of them. Only 1.3% of the taxa were found to be common to all ten islets, and 0.4% common to nine

Table 2. Numbers of vascular plant taxa in the flora of the two studied islet groups. – AG = Amvrakikos Gulf islets; ML = Mesolongi Lagoon islets.

	Area	Families	Genera	Species	Subspecies	Taxa	%
Gymnosperms	AG	2	2	2	0	2	1.4
	ML	1	1	1	0	1	0.6
Angiosperms	AG	43	115	128	12	140	98.6
	ML	45	125	154	9	163	99.4
Total	AG	45	117	130	12	142	100
	ML	46	126	155	9	164	100

Table 3. Life-form spectrum of the flora of the two studied islet groups.

Life-form category	Amvrakikos Gulf islets		Mesolongi Lagoon islets	
	Number of taxa	%	Number of taxa	%
Phanerophytes	15	10.6	18	11
Chamaephytes	12	8.4	11	6.7
Hemicryptophytes	24	16.9	31	18.9
Geophytes	17	12	17	10.4
Therophytes	74	52.1	87	53
Total	142	100	164	100

Table 4. Chorological spectrum of the flora of the two studied islet groups.

Chorological category	Amvrakikos Gulf islets		Mesolongi Lagoon islets	
	Number of taxa	%	Number of taxa	%
1. Widespread taxa	34	24.1	51	31.5
Cosmopolitan	7	5	12	7.4
Subtropical-tropical	3	2.1	4	2.5
Euro-Siberian	2	1.4	3	1.8
European-SW Asian	13	9.2	20	12.4
Paleotemperate	9	6.4	12	7.4
2. Mediterranean taxa	106	75.2	108	66.7
East Mediterranean	5	3.5	5	3.1
Mediterranean	69	49	61	37.7
Mediterranean-Atlantic	7	5	12	7.4
Mediterranean-European	15	10.6	14	8.6
Mediterranean-SW Asian	10	7.1	16	9.9
3. Alien taxa	1	0.7	3	1.8
Total	141	100	162	100

of them. The most widespread plant taxa recorded on the studied islets are *Asparagus acutifolius*, *Limbarda crithmoides* and *Pistacia lentiscus* (on all ten studied islets), *Smilax aspera* (on nine islets) and *Asphodelus ramosus*, *Elytrigia juncea* and *Rubia peregrina* (on eight islets). Except the above-mentioned taxa, there are others found on five or all six islets of the Amvrakikos Gulf, such as *Lonicera implexa*, *Myrtus communis* and *Olea euro-*

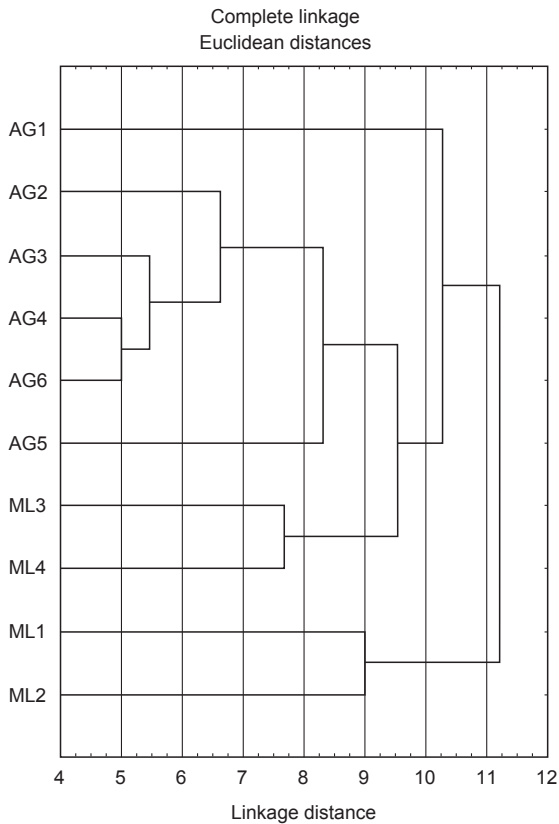


Fig. 2. Hierarchical cluster analysis showing floristic relations between the studied islets (linkage method: complete linkage, Euclidean distances). – For islet codes see Table 1.

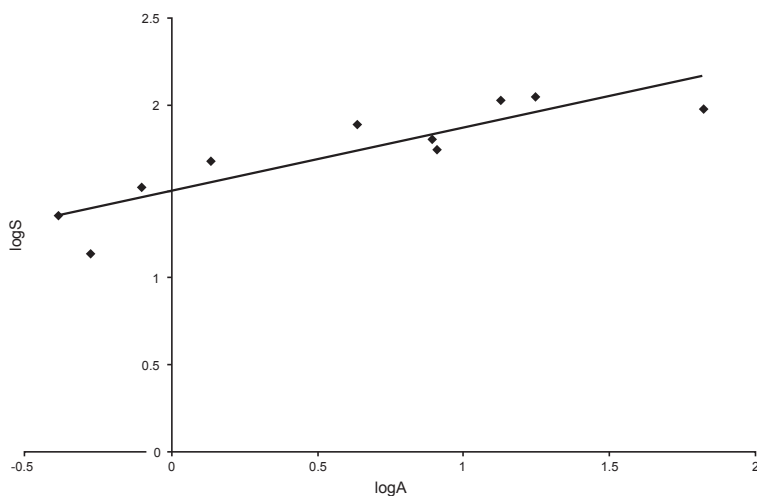


Fig. 3. Plant species-area relationship (SAR) of the studied islets ($\log S = 1.507 + 0.343 \log A$, $R^2 = 0.741$, $R = 0.861$).

3. Statistical analysis of the factors affecting plant species richness

The Spearman correlation coefficient was calculated among biogeographical factors to evaluate multi-collinearity of these predictor variables. Surface area (A), elevation (E) and distance to the mainland (Dm) are not correlated to each other.

The results of simple regression analyses (log-log) of plant species richness indicated island surface area as a predictor variable of species richness since they are strongly correlated ($R^2 = 0.741$). Elevation and distance to the mainland do not show a significant effect on species richness. Fig. 3 presents the logarithmic species-area relationship (SAR) for the islets studied with the equation $\log S = 1.507 + 0.343 \log A$. Stepwise multiple regression analyses were conducted among the number of plant taxa and the set of the studied biogeographical factors. Only the surface area (A) is a strong predictor variable of plant species richness since plant species richness is not significantly correlated with elevation (E) and distance to the adjacent species pool (Dm).

Discussion

There has been a complete gap so far concerning plant species richness of the islets studied, which are included in the protected areas of the “Amvrakikos Wetlands National Park” and the “National Park of Mesolongi – Aitoliko lagoons, estuaries of Acheloos and Evinos River and Echinades islet group”. During our field investigations on the six islets in the Amvrakikos Gulf and the four islets in the

Mesolongi Lagoon, 226 plant taxa were registered representing 11.1 % of the total flora of the Ionian area (2027 taxa) as recorded by Dimopoulos & al. (2013). A large proportion of these taxa belong to the families *Asteraceae*, *Fabaceae* and *Poaceae*, which are among the families adapted best to the ecological conditions of the Mediterranean area as is also confirmed by many floristic studies of Greek insular areas (Panitsa & Tzanoudakis 2001, 2010; Kougioumoutzis & al. 2012; etc.). The Mediterranean character of the flora of the studied islet groups is reflected also by the high proportions of the Mediterranean plant taxa, in conjunction with the high percentage of therophytes.

Floristic cross-correlations of the studied islets (beta-diversity) according to the Sørensen similarity coefficient revealed values from 0.09, indicating high floristic heterogeneity, to 0.61, showing significant floristic similarity. Hierarchical cluster analyses divided the islets studied into three subgroups mainly based on surface area and the geographical position.

paea subsp. *europaea*, and also on all four islets of the Mesolongi Lagoon, such as *Juncus maritimus*, *Limonium narbonense*, *L. virgatum*, *Salsola tragus*, *Scirpoides holoschoenus* and *Tamarix hampeana*.

Table 5. Plant taxa on the two studied islet groups that are registered under a protection status. – AG = Amvrakikos Gulf islets; ML = Mesolongi Lagoon islets.

Taxon	AG	ML	Presidential Decree 67/1981	CITES	IUCN	European Red List	UNEP WCMC
<i>Achillea maritima</i>	–	×	–	–	–	–	×
<i>Aegilops biuncialis</i>	–	×	–	–	–	–	×
<i>Aeluropus litoralis</i>	–	×	–	–	–	–	×
<i>Alkanna tinctoria</i>	–	×	–	–	–	–	×
<i>Arthrocnemum macrostachyum</i>	×	×	–	–	–	–	×
<i>Calystegia soldanella</i>	–	×	–	–	–	–	×
<i>Centaureum erythraea</i>	×	×	–	–	LC	–	–
<i>Cyclamen hederifolium</i>	×	–	–	×	–	–	×
<i>Ephedra foeminea</i>	×	–	–	–	LC	–	–
<i>Euphorbia dendroides</i>	–	×	–	×	–	–	×
<i>Euphorbia paralias</i>	×	×	–	–	–	–	×
<i>Euphorbia pepilis</i>	–	×	–	–	–	–	×
<i>Geranium purpureum</i>	–	×	–	–	–	–	×
<i>Glaucium flavum</i>	–	×	–	–	–	–	×
<i>Juncus inflexus</i>	×	×	–	–	LC	–	–
<i>Juniperus phoenicea</i>	×	×	–	–	LC	–	×
<i>Lagurus ovatus</i>	×	×	–	–	–	–	×
<i>Medicago marina</i>	–	×	–	–	–	LC	×
<i>Nerium oleander</i>	–	×	–	–	LC	–	–
<i>Ononis reclinata</i>	–	×	–	–	–	–	×
<i>Ophrys scolopax</i> subsp. <i>cornuta</i>	×	–	×	×	–	–	–
<i>Orobanche minor</i>	–	×	–	–	–	–	×
<i>Pancratium maritimum</i>	–	×	–	–	–	–	×
<i>Parapholis incurva</i>	×	×	–	–	–	–	×
<i>Phragmites australis</i>	×	×	–	–	LC	LC	–
<i>Pistacia lentiscus</i>	×	×	–	–	–	–	×
<i>Prasium majus</i>	×	×	–	–	–	–	×
<i>Ranunculus chius</i>	–	×	–	–	–	–	×
<i>Reichardia picroides</i>	×	×	–	–	–	–	×
<i>Schoenus nigricans</i>	–	×	–	–	LC	–	–
<i>Scirpoides holoschoenus</i>	–	×	–	–	LC	–	–
<i>Serapias vomeracea</i>	×	–	×	×	–	LC	×
<i>Tamarix hampeana</i>	×	×	–	–	–	–	×
<i>Tetragonolobus purpureus</i>	×	–	–	–	LC	–	–
<i>Trifolium angustifolium</i>	×	×	–	–	LC	–	–
<i>Trifolium scabrum</i>	–	×	–	–	LC	–	–
<i>Trifolium tomentosum</i>	–	×	–	–	–	–	×
<i>Vulpia fasciculata</i>	–	×	–	–	–	–	×

Furthermore, the proportion of islets on which a taxon occurs showed that about 20 % of the taxa are frequent on more than half of the islets, while 72.6 % of the taxa are rare or not common in the islet group, being found only on one to three of the islets. Island similarities concerning all native taxa show a significant geographical component, reflecting the spatial autocorrelation of floras before the fragmentation of the mainland – or the effects of intensive post-fragmentation dispersal (Triantis & al. 2008b).

The high occurrence on the studied islets of taxa such as *Myrtus communis*, *Olea europaea* subsp. *europaea* and *Pistacia lentiscus* is a nice example of one of the most outstanding ecological plant-avian frugivore interactions. Panitsa & Tzanoudakis (2010) also mentioned that the

high incidence of *Olea europaea* and *Pistacia lentiscus* represent characteristic examples of plant species introduction via sea birds to islets around the E Aegean island of Leros.

As the islet groups of the Amvrakikos Gulf and Mesolongi Lagoon belong to national parks that are nature reserves under the International Ramsar Convention and designated as Important Bird Areas, it is critical to mention here that the islets studied, as a part of warm lowlands in the Mediterranean, are also important wintering quarters for European frugivorous birds. González-Varo (2010) suggested that, in a conservation context, it may be possible to sustain frugivore animal numbers by promoting succession within extant patches of vegetation

instead of increasing woodland cover (reforestation) at landscape level.

In addition, the role of the Mesolongi Lagoon islets as barrier islets should be noted. Looney & Gibson (1995) noticed that on coastal barrier islands the seed bank of low disturbance, late-succession vegetation types was well developed in contrast to a poorly developed and transient seed bank occurring in more frequently disturbed, early successional dredge-spoil unvegetated areas and strand. Stallins & Parker (2003) outlined the complex interplay between disturbance and environmental gradients (plant species abundances, landform-mediated physical gradients, sediment mobility) that influence biogeographical patterns. This is in accordance with the relatively high plant species richness and the absence of endemic plant taxa on the investigated islets that could additionally be attributed to their low elevation and their relatively recent isolation from the mainland.

The investigation of factors affecting plant species richness showed that, for the islet groups studied here, the total species richness is strongly correlated to island surface area. There is a strong species-area relationship ($R^2 = 0.741$), as was also found for the islands of the S Aegean ($R^2 = 0.73$) by Kagiampaki & al. (2011). This corroborates that, in general, surface area is considered the most influential explanatory variable of species richness in island biogeography (Whittaker & Fernández-Palacios 2007; Triantis & al. 2008a, 2008b).

The logarithmic approach of the power function ($S = cAz$) of Arrhenius's model (1921) explains best the variation in species richness (Willerslev & al. 2002) and shows higher slopes for "island"-like species-area relationships than "mainland" relationships according to Rosenzweig (1995). The slope as expressed by the z -value of the species-area relationship for the studied islet groups is 0.343. This is not close to the "canonical" value of 0.263 set up by Preston (1962) and MacArthur & Wilson (1967), but it is within the range of 0.2–0.5 proposed by Rosenzweig (1995) for island groups indicating the above-mentioned "mainland" species-area relationship. It should be mentioned that for the neighbouring islet group of Echinades situated in the Ionian open sea, the z -value is 0.236 (Iliadou & al. 2014). The slope (z -value) shows the increase rate of species richness with area and it can vary according to the examined geographical unit and the taxonomic group analysed (Duarte & al. 2008; MacArthur & Wilson 1967).

In conclusion, the present study shows that the islet groups of the Amvrakikos Gulf and the Mesolongi Lagoon host a significant plant species richness and high overall heterogeneity. The role of geographical position, geological history, palaeogeography and of variables such as island surface area determines the individual islet floras. The inventory of the plant species diversity of the islets in the Amvrakikos Gulf and the Mesolongi Lagoon, the exploration of plant species-richness patterns and of the effects of factors affecting them, fills one more gap

in the floristic information available for both the "Amvrakikos Wetlands National Park" and the "National Park of Mesolongi – Aitoliko lagoons, estuaries of Acheloos and Evinos River and Echinades islet group", thus adding to and complementing the case of the Echinades islets group (Iliadou & al. 2014). In order to propose and implement proper measures for the conservation management of species and habitats in the given protected areas, knowledge of the species diversity basically presented here is of crucial importance.

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Appendix: Vascular plant catalogue

Symbols and abbreviations:

Life-form categories (following Dimopoulos & al. 2013):
C = chamaephyte; **H** = hemicryptophyte; **G** = geophyte;
P = phanerophyte; **T** = therophyte.

Chorological categories (following Dimopoulos & al. 2013): **Co** = Cosmopolitan; **EA** = European-SW Asian; **EM** = East Mediterranean; **ES** = Euro-Siberian; **MA** = Mediterranean-Atlantic; **Me** = Mediterranean; **ME** = Mediterranean-European; **MS** = Mediterranean-SW Asian; **Pt** = Paleotemperate; **ST** = Subtropical-tropical.

AG1–AG6, ML1–ML4 = Amvrakikos Gulf and Mesolongi Lagoon islet codes; see Table 1.

[] = Alien taxa according to Arianoutsou & al. (2010).

Gymnosperms

Cupressaceae

Juniperus phoenicea L. – P, Me; AG1, AG6, ML1, ML2, ML3, ML4.

Ephedraceae

Ephedra foeminea Forssk. – P, Me; AG5.

Angiosperms

Alliaceae

Allium ampeloprasum L. – G, Me; AG1, AG3, AG5, AG6.

Allium subhirsutum L. – G, Me; AG1, AG2, AG3.

Amaryllidaceae

Narcissus tazetta L. – G, MS; AG1, AG2, AG5.

Pancratium maritimum L. – G, Me; ML3.

Anacardiaceae

Pistacia lentiscus L. – P, Me; AG1, AG2, AG3, AG4, AG5, AG6, ML1, ML2, ML3, ML4.

Apiaceae

Crithmum maritimum L. – C, ME; AG1.

Daucus guttatus Sm. – T, Me; ML1, ML2, ML3.

Echinophora spinosa L. – H, Me; ML1, ML2.

Eryngium maritimum L. – G, ME; ML1, ML2, ML3.

Ferula communis subsp. *glauca* (L.) Rouy & Camus – H, Me; AG4, AG5.

Oenanthe silaifolia M. Bieb. – H, EA; AG1, AG2.

Opopanax chironium (L.) W. D. J. Koch – H, ME; AG1, AG2, AG3, AG4, AG5, ML3.

Pseudorlaya pumila (L.) Grande – T, Me; ML1, ML2.

Torilis nodosa (L.) Gaertn. – T, EA; ML1, ML2, ML3.

Apocynaceae

Nerium oleander L. – P, Me; ML1, ML3.

Araceae

Arisarum vulgare Targ. Tozz. – G, Me; AG1, AG2, AG3, AG5, AG6.

Arum italicum Mill. subsp. *italicum* – G, ME; AG5, AG6.

Asparagaceae

Asparagus acutifolius L. – P, Me; AG1, AG2, AG3, AG4, AG5, AG6, ML1, ML2, ML3, ML4.

Asphodelaceae

Asphodelus ramosus L. subsp. *ramosus* – G, Me; AG1, AG2, AG3, AG5, ML1, ML2, ML3, ML4.

Asteraceae

Achillea maritima (L.) Ehrend. & Y. P. Guo – C, MA; ML1, ML2.

Aetheorhiza bulbosa (L.) Cass. – G, EM; ML2, ML3, ML4.

Andryala integrifolia L. – T, Me; ML1.

Anthemis arvensis subsp. *incrassata* (Loisel.) Nyman – T, Me; AG1, ML2, ML3.

Anthemis chia L. – T, Me; AG1, ML2.

Anthemis tomentosa L. – T, EM; AG1, AG5, ML1, ML2.

Bellis sylvestris Cirillo – H, Me; AG1, AG2.

Carduus pycnocephalus L. – H, ME; AG5, ML1, ML3.

Carlina gummifera (L.) Less. – H, Me; ML2.

Carlina lanata L. – T, Me; AG1, ML1.

Carthamus lanatus L. – T, Me; AG1, AG5.

Crepis multiflora Sm. – T, EM; ML1.

[*Erigeron bonariensis* L.] – T, [Neotrop]; ML1, ML4.

Filago gallica L. – T, MA; ML2.

Glebionis segetum (L.) Fourr. – T, Me; AG5.

Hedynois rhagadioloides (L.) F. W. Schmidt – T, Me; AG1, AG2, AG4, AG5, ML1.

Hyoseris scabra L. – T, Me; AG1.

Hypochaeris achyrophorus L. – T, Me; AG1, AG2, AG3, AG4, AG5, ML1, ML2.

Limbarda crithmoides (L.) Dumort. – C, MA; AG1, AG2, AG3, AG4, AG5, AG6, ML1, ML2, ML3, ML4.

Pallenis spinosa (L.) Cass. – T, Me; AG1, AG2, AG4, ML4.

Pulicaria odora (L.) Rchb. – H, Me; AG1.

Reichardia picroides (L.) Roth – H, Me; AG1, AG2, AG3, AG4, ML1, ML2, ML3.

Scolymus hispanicus L. – H, ME; AG1, ML1, ML3.

Silybum marianum (L.) Gaertn. – H, Me; ML1.

Sonchus asper (L.) Hill – T, Pt; AG3, AG4, AG5, ML4.

Sonchus oleraceus L. – T, ME; AG1, AG3, ML3, ML4.

[*Symphotrichum squamatum* (Spreng.) G. L. Nesom] – T, [Neotrop]; ML3.

Taraxacum sp. – H; ML3.

Urospermum picroides (L.) F. W. Schmidt – T, Me; AG1, AG5, ML1, ML3, ML4.

[*Xanthium orientale* subsp. *italicum* (Moretti) Greuter] – T, [S-Eur.]; ML1, ML2, ML3.

Boraginaceae

Alkanna tinctoria Tausch – H, Me; ML1, ML2.

Borago officinalis L. – T, Me; AG5.
Cerintho major L. – T, MS; AG5.
Echium italicum L. – H, MS; ML2.
Echium plantagineum L. – T, ME; ML3.

Brassicaceae

Cakile maritima Scop. – T, ME; AG1, AG5, ML2, ML3, ML4.
Capsella bursa-pastoris (L.) Medik. – H, Co; AG3.
Enarthrocarpus arcuatus Labill. – T, EM; AG5.
Hirschfeldia incana (L.) Lagr.-Foss. – H, EA; ML1.
Malcolmia maritima (L.) R. Br. – T, Me; AG1, AG5, ML3, ML4.
Matthiola tricuspidata (L.) R. Br. – T, Me; AG1, AG5, ML1, ML2, ML3, ML4.
Rapistrum rugosum (L.) All. – T, EA; AG1.

Caprifoliaceae

Lonicera implexa Aiton – P, Me; AG1, AG2, AG3, AG4, AG5, AG6, ML1.

Caryophyllaceae

Cerastium glutinosum Fr. – T, EA; ML1, ML2.
Cerastium semidecandrum L. – T, EA; ML4.
Petrorhagia dubia (Raf.) G. López & Romo – T, Me; ML1, ML2.
Sagina maritima G. Don – T, MA; ML4.
Silene nocturna L. – T, Me; ML1.
Silene vulgaris subsp. *macrocarpa* Turrill – H, Me; AG5.
Spergularia marina (L.) Besser – T, Pt; ML1.
Stellaria apetala Ucria – T, EA; ML3.

Chenopodiaceae

Arthrocnemum macrostachyum (Moric.) K. Koch – C, Me; AG1, ML2, ML3, ML4.
Atriplex prostrata DC. – T, ES; AG1, AG5, ML1, ML3.
Beta vulgaris subsp. *maritima* (L.) Arcang. – H, EA; AG4, ML1.
Chenopodium murale (L.) S. Fuentes & al. – T, EA; AG1.
Halimione portulacoides (L.) Aellen – C, ME; AG1, AG3, AG5, AG6, ML1, ML3, ML4.
Salicornia perennans Willd. subsp. *perennans* – T, EA; ML1, ML3, ML4.
Salsola soda L. – T, Pt; AG1, AG2, AG5, ML2, ML4.
Salsola tragus L. – T, Pt; ML1, ML2, ML3, ML4.
Sarcocornia fruticosa (L.) A. J. Scott – C, MA; AG1, AG2, AG5, ML2, ML3, ML4.
Sarcocornia perennis (Mill.) A. J. Scott – C, MA; AG1, ML1, ML2, ML3, ML4.
Suaeda maritima (L.) Dumort. – T, EA; ML1, ML3, ML4.

Cistaceae

Cistus salviifolius L. – P, Me; ML1, ML2, ML4.
Fumana thymifolia (L.) Webb – C, Me; AG1.

Convolvulaceae

Calystegia soldanella (L.) Roem. & Schult. – G, Co; ML2.
Convolvulus arvensis L. – G, Co; ML2.
Convolvulus elegantissimus Mill. – H, Me; AG1.

Cyperaceae

Carex divisa Huds. – G, EA; AG5, ML3.
Carex extensa Gooden. – H, MA; AG1, ML1, ML2, ML3.
Carex flacca subsp. *serrulata* (Spreng.) Greuter – G, MS; AG1, AG2, AG5.
Cyperus capitatus Vand. – G, Me; ML2.
Schoenus nigricans L. – H, Co; ML2, ML3, ML4.
Scirpoides holoschoenus (L.) Soják – G, Pt; ML1, ML2, ML3, ML4.

Dipsacaceae

Knautia integrifolia (L.) Bertol. – T, Me; AG5.

Ericaceae

Arbutus unedo L. – P, Me; AG2, AG6.

Euphorbiaceae

Euphorbia dendroides L. – P, Me; ML1, ML2.
Euphorbia exigua L. – T, ME; AG2, AG5.
Euphorbia helioscopia L. – T, Co; ML1.
Euphorbia paralias L. – C, Me; AG1, ML1, ML2, ML3, ML4.
Euphorbia peplis L. – T, ME; ML1.
Euphorbia peplus L. – T, Co; AG1, AG3, ML2.
Mercurialis annua L. – T, Pt; AG1, AG5, ML1.

Fabaceae

Anagyris foetida L. – P, Me; ML1, ML4.
Anthyllis hermanniae L. – C, Me; ML1, ML2, ML4.
Calicotome villosa (Poir.) Link – P, Me; AG1, AG2.
Dorycnium hirsutum (L.) Ser. – C, Me; AG1.
Genista acanthoclada DC. – P, EM; ML2, ML4.
Lotus corniculatus L. – H, EA; ML1.
Lotus ornithopodioides L. – T, Me; AG1, AG2, AG3, AG5.
Medicago marina L. – C, ME; ML2.
Medicago minima (L.) Bartal. – T, Pt; AG1, AG2.
Medicago orbicularis (L.) Bartal. – T, MS; ML1.
Medicago polymorpha L. – T, Pt; AG1, AG2, AG5, ML1, ML3.
Medicago truncatula Gaertn. – T, MS; AG1, ML1.
Melilotus indicus (L.) All. – T, EA; AG1, ML1, ML3.
Melilotus sulcatus Desf. – T, Me; AG1, AG5.
Ononis reclinata L. – T, ME; ML1, ML2.
Scorpiurus muricatus L. – T, Me; AG1, ML2.
Securigera securidaca (L.) Degen & Dörfel. – T, Me; AG5.
Spartium junceum L. – P, Me; AG2, AG3, AG5, AG6.
Tetragonolobus purpureus Moench – T, Me; AG5.
Trifolium angustifolium L. – T, EA; AG1, AG2, AG5, ML1, ML2, ML4.

Trifolium campestre Schreb. – T, EA; AG1, AG5, ML1, ML2.

Trifolium lappaceum L. – T, MS; AG1, ML1, ML2.

Trifolium nigrescens Viv. – T, Me; AG1.

Trifolium scabrum L. – T, EA; ML1, ML2, ML4.

Trifolium stellatum L. – T, Me; ML1.

Trifolium tomentosum L. – T, Me; ML1.

Trigonella corniculata subsp. *balansae* (Boiss. & Reut.) Lassen – T, EM; AG1, AG5.

Vicia angustifolia L. – T, Pt; AG2, ML3.

Vicia villosa subsp. *microphylla* (d'Urv.) P. W. Ball – T, EM; AG5.

Fumariaceae

Fumaria macrocarpa Parl. – T, Me; AG1, AG2, AG3, AG5.

Gentianaceae

Blackstonia perfoliata (L.) Huds. subsp. *perfoliata* – T, ME; AG1, AG5, ML1, ML2, ML3, ML4.

Centaurium erythraea Raf. – H, EA; AG1, AG5, ML2.

Centaurium tenuiflorum (Hoffmanns. & Link) Fritsch – T, ME; AG1.

Geraniaceae

Geranium purpureum Vill. – T, Me; ML1, ML3.

Geranium rotundifolium L. – T, Pt; AG5.

Hyacinthaceae

Drimia numidica (Jord. & Fourr.) J. C. Manning & Goldblatt – G, Me; AG2, ML1.

Muscari comosum (L.) Mill. – G, ME; AG1, AG2, AG5.

Hypericaceae

Hypericum tetrapterum Fr. – H, EA; AG1.

Iridaceae

Gladiolus italicus Mill. – G, MS; AG1, AG2, ML1, ML2.

Juncaceae

Juncus acutus L. – H, ES; AG1, AG5, ML1, ML2, ML3, ML4.

Juncus hybridus Brot. – T, MA; ML1, ML2, ML4.

Juncus inflexus L. – H, Pt; AG1, ML1, ML2, ML3, ML4.

Juncus maritimus Lam. – G, ME; ML1, ML2, ML3, ML4.

Lamiaceae

Micromeria graeca (L.) Rchb. – C, Me; AG1.

Prasium majus L. – C, Me; AG1, AG2, AG3, AG5, ML1, ML2.

Thymbra capitata (L.) Cav. – C, Me; AG1, ML1, ML2.

Linaceae

Linum bienne Mill. – H, Me; ML2.

Linum corymbulosum Rchb. – T, EA; AG1, ML2.

Linum strictum L. – T, Me; ML1, ML2.

Malvaceae

Malva parviflora L. – T, MS; ML1, ML3.

Malva punctata (All.) Alef. – T, Me; AG5.

Moraceae

Ficus carica L. – P, MS; AG5, ML3.

Myrtaceae

Myrtus communis L. – P, Me; AG1, AG2, AG3, AG4, AG5, ML1, ML4.

Oleaceae

Olea europaea L. subsp. *europaea* – P, Me; AG1, AG2, AG4, AG5, AG6, ML1, ML4.

Orchidaceae

Ophrys scolopax subsp. *cornuta* (Steven) E. G. Camus – G, ME; AG1.

Serapias vomeracea (Burm. f.) Briq. – G, ME; AG1.

Orobanchaceae

Orobanche minor Sm. – T, EA; ML1, ML2.

Papaveraceae

Glaucium flavum Crantz – H, ME; ML1, ML4.

Plantaginaceae

Plantago afra L. – T, Me; AG1.

Plantago coronopus L. – T, MA; ML1, ML2.

Plantago crassifolia Forssk. – H, Me; ML1, ML2.

Plantago lagopus L. – T, Me; AG1, ML1.

Plantago lanceolata L. – H, Co; AG1, AG2, ML2.

Plumbaginaceae

Limonium narbonense Mill. – H, MS; AG1, AG5, ML1, ML2, ML3, ML4.

Limonium virgatum (Willd.) Fourr. – H, Me; AG1, AG5, ML1, ML2, ML3, ML4.

Poaceae

Aegilops biuncialis Vis. – T, MS; ML1.

Aeluropus littoralis (Gouan) Parl. – G, MS; ML1.

Avena barbata Link – T, Me; AG1, AG2, AG3, AG4, AG5, ML1.

Brachypodium distachyon (L.) P. Beauv. – T, MS; AG1, ML1, ML2.

Brachypodium retusum (Pers.) P. Beauv. – H, Me; AG1, AG2, AG3, AG4, AG5, ML1, ML2.

Briza maxima L. – T, ST; ML1, ML2.

Bromus alopecuroides Poir. – T, Me; AG1.

Bromus diandrus Roth – T, Me; ML1.

Bromus madritensis L. – T, MS; ML1.

Bromus rigidus Roth – T, ST; AG1, AG2, ML1.

Bromus rubens L. – T, MS; AG3, AG5.

- Bromus squarrosus* L. – T, Pt; ML2.
Bromus sterilis L. – T, MS; ML1, ML2, ML3.
Catapodium marinum (L.) C. E. Hubb. – T, MA; AG1, AG3.
Catapodium rigidum (L.) C. E. Hubb. – T, Me; AG1, AG3, AG5, ML1, ML2, ML4.
Cynosurus echinatus L. – T, Me; AG5, ML1, ML2, ML3.
Dactylis glomerata L. – H, Pt; AG1, AG2, AG3, AG4, AG5.
Digitaria sanguinalis (L.) Scop. – T, Co; AG5.
Elytrigia juncea (L.) Nevski – G, Me; AG1, AG2, AG3, AG4, AG5, ML2, ML3, ML4.
Festuca arundinacea Schreb. – H, Pt; ML2.
Gastridium ventricosum (Gouan) Schinz & Thell. – T, Me; AG1.
Gaudinia fragilis (L.) P. Beauv. – T, Me; AG1, AG5, ML2.
Hordeum murinum subsp. *leporinum* (Link) Arcang. – T, Me; AG1, AG2, ML1, ML2.
Imperata cylindrica (L.) Raeusch. – G, Co; ML3, ML4.
Lagurus ovatus L. – T, Me; AG1, AG3, AG5, ML1, ML2, ML3.
Lolium perenne L. – H, ES; ML1, ML2.
Parapholis incurva (L.) C. E. Hubb. – T, MA; AG1, AG2, AG4, AG5, ML1, ML2.
[*Phalaris canariensis* L.] – T, [Macaronesian]; AG2, AG4, AG5.
Phragmites australis (Cav.) Steud. – G, Co; AG1, ML1, ML2, ML3, ML4.
Piptatherum miliaceum (L.) Coss. – H, Me; AG1.
Polypogon monspeliensis (L.) Desf. – T, ST; AG1, ML1, ML2, ML4.
Puccinellia distans (L.) Parl. – H, Pt; ML2, ML4.
Rostraria cristata (L.) Tzvelev – T, Co; AG1, ML1.
Sporobolus pungens (Schreb.) Kunth – G, ST; AG1, ML2, ML4.
Vulpia fasciculata (Forssk.) Fritsch – T, MA; ML1, ML2.
- Polygonaceae**
Rumex bucephalophorus L. – T, Me; ML1, ML2, ML3.
Rumex conglomeratus Murray – H, EA; ML2, ML3.
- Primulaceae**
Anagallis arvensis L. – T, Co; AG1, AG2, AG3, ML1, ML2, ML4.
Cyclamen hederifolium Aiton – G, Me; AG1, AG3, AG5.
- Ranunculaceae**
Ranunculus chius DC. – T, MS; ML1.
Ranunculus neapolitanus Ten. – H, Me; AG1.
- Rhamnaceae**
Rhamnus alaternus L. – P, Me; ML2, ML4.
- Rosaceae**
Rosa sp. – P; AG2, AG4, AG5.
Rubus sanctus Schreb. – P, MS; ML1.
- Rubiaceae**
Crucianella latifolia L. – T, ME; AG1.
Galium aparine L. – T, EA; AG5, AG6, ML3.
Rubia peregrina L. – P, MA; AG1, AG2, AG3, AG4, AG5, ML1, ML2, ML3.
Sherardia arvensis L. – T, EA; AG5.
Theligonum cynocrambe L. – T, Me; AG2.
Valantia hispida L. – T, Me; ML2, ML3.
Valantia muralis L. – T, Me; AG1, AG3, AG5, ML2, ML3.
- Scrophulariaceae**
Verbascum blattaria L. – H, EA; ML1.
Verbascum sinuatum L. – H, MS; ML1, ML3.
- Smilacaceae**
Smilax aspera L. – P, Me; AG1, AG2, AG3, AG4, AG5, AG6, ML1, ML2, ML4.
- Solanaceae**
Solanum nigrum L. – T, Co; ML4.
- Tamaricaceae**
Tamarix hampeana Boiss. & Heldr. – P, EM; AG1, AG5, ML1, ML2, ML3, ML4.
- Urticaceae**
Urtica urens L. – T, Co; ML4.
- Vitaceae**
Vitis sp. – P; ML1.