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)

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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, Kafafourko lagoon and Korakonisia”. 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
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 AitoloaKarnania as 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

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Table 1. Geographical and ecological information about the two studied islet groups.

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

Fig. 1. Map of the two studied islet groups. The numbers correspond to the islet codes in Table 1.
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 tecting the entrance to the gulf, concluded that tsunami system and related extensive beachrock sequences pro-
costal zone, which is characterized by an active barrier

The islets in the Amvrakikos Gulf are composed of Trias-

The Mesolongi Lagoon is connected to the Gulf of

Based on the climatic diagram of Emberger (1952),

Three habitat types of Annex I of the Directive 92/43/

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,

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, Symphyotrichum 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 of them. The most widespread plant taxa recorded on the studied islets are Asparagus acutifolius, Limbarda criithmoïdes 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 impexa, Myrtus communis and Olea euro-

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

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

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

<table>
<thead>
<tr>
<th>Life-form category</th>
<th>Amvrakikos Gulf islets</th>
<th>Mesolongi Lagoon islets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of taxa</td>
<td>%</td>
<td>Number of taxa</td>
</tr>
<tr>
<td>Phanerophytes</td>
<td>15</td>
<td>18</td>
</tr>
<tr>
<td>Chamaephytes</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Hemicryptophytes</td>
<td>24</td>
<td>31</td>
</tr>
<tr>
<td>Geophytes</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Therophytes</td>
<td>74</td>
<td>87</td>
</tr>
<tr>
<td>Total</td>
<td>142</td>
<td>164</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Chorological category</th>
<th>Amvrakikos Gulf islets</th>
<th>Mesolongi Lagoon islets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of taxa</td>
<td>%</td>
<td>Number of taxa</td>
</tr>
<tr>
<td>1. Widespread taxa</td>
<td>34</td>
<td>51</td>
</tr>
<tr>
<td>Cosmopolitan</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Subtropical-tropical</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Euro-Siberian</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>European-SW Asian</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>Paleotemperate</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>2. Mediterranean taxa</td>
<td>106</td>
<td>108</td>
</tr>
<tr>
<td>East Mediterranean</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Mediterranean</td>
<td>69</td>
<td>61</td>
</tr>
<tr>
<td>Mediterranean-Atlantic</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Mediterranean-European</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>Mediterranean-SW Asian</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>3. Alien taxa</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>141</td>
<td>162</td>
</tr>
</tbody>
</table>

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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.

\textit{paea} subsp. \textit{europaea}, and also on all four islets of the Mesolongi Lagoon, such as \textit{Juncus maritimus}, \textit{Limonium narbonense}, \textit{L. virgatum}, \textit{Salsola tragus}, \textit{Scirpoides holoschoenus} and \textit{Tamarix hampeana}. 
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 low-lands 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.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>AG</th>
<th>ML</th>
<th>Presidential Decree 67/1981</th>
<th>CITES</th>
<th>IUCN European Red List</th>
<th>UNEP WCMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achillea maritima</td>
<td>×</td>
<td>×</td>
<td></td>
<td>–</td>
<td>–</td>
<td>×</td>
</tr>
<tr>
<td>Aegilops biuncialis</td>
<td>×</td>
<td>–</td>
<td></td>
<td>–</td>
<td>–</td>
<td>×</td>
</tr>
<tr>
<td>Aeluropus littoralis</td>
<td>×</td>
<td>–</td>
<td></td>
<td>–</td>
<td>–</td>
<td>×</td>
</tr>
<tr>
<td>Alkanna tinctoria</td>
<td>×</td>
<td>–</td>
<td></td>
<td>–</td>
<td>–</td>
<td>×</td>
</tr>
<tr>
<td>Arthrocennum macrostachyum</td>
<td>×</td>
<td>×</td>
<td></td>
<td>–</td>
<td>–</td>
<td>×</td>
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<td>Calystegia soldanella</td>
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<td>×</td>
</tr>
<tr>
<td>Centaurium erythraea</td>
<td>×</td>
<td>×</td>
<td></td>
<td>LC</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Cyclamen hederifolium</td>
<td>×</td>
<td>–</td>
<td></td>
<td>–</td>
<td>X</td>
<td>×</td>
</tr>
<tr>
<td>Ephedra foeminea</td>
<td>×</td>
<td>–</td>
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<td>LC</td>
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<td>–</td>
<td></td>
<td>X</td>
<td>–</td>
<td>×</td>
</tr>
<tr>
<td>Euphorbia paralias</td>
<td>×</td>
<td>×</td>
<td></td>
<td>–</td>
<td>–</td>
<td>×</td>
</tr>
<tr>
<td>Euphorbia peplis</td>
<td>×</td>
<td>–</td>
<td></td>
<td>–</td>
<td>–</td>
<td>×</td>
</tr>
<tr>
<td>Geranium purpureum</td>
<td>×</td>
<td>–</td>
<td></td>
<td>–</td>
<td>–</td>
<td>×</td>
</tr>
<tr>
<td>Glaucium flavum</td>
<td>×</td>
<td>×</td>
<td></td>
<td>–</td>
<td>–</td>
<td>×</td>
</tr>
<tr>
<td>Juniperus phoenica</td>
<td>×</td>
<td>×</td>
<td></td>
<td>LC</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Lagurus ovatus</td>
<td>×</td>
<td>×</td>
<td></td>
<td>–</td>
<td>–</td>
<td>X</td>
</tr>
<tr>
<td>Medicago marina</td>
<td>×</td>
<td>×</td>
<td></td>
<td>–</td>
<td>LC</td>
<td>–</td>
</tr>
<tr>
<td>Nierium oleander</td>
<td>×</td>
<td>×</td>
<td></td>
<td>LC</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Ononis reclinata</td>
<td>×</td>
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<tr>
<td>Ophrys scolopax subsp. cornuta</td>
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<td>Orobanche minor</td>
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<td>Panthranium maritimum</td>
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<tr>
<td>Parapholis incurva</td>
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<td>Phragmites australis</td>
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<td>Pistacia lentiscus</td>
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<td>Prasium majus</td>
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<td>Ranunculus chius</td>
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<td>Reichardia picroides</td>
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<td>Schoenus nigricans</td>
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<tr>
<td>Scirpoides holoschoenus</td>
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<td>Serapias vomeracea</td>
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<td>Tamariar hampeana</td>
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<tr>
<td>Tetragonolobus purpureus</td>
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<td>LC</td>
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<td>Trifolium angustifolium</td>
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<tr>
<td>Trifolium scabrum</td>
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<tr>
<td>Trifolium tomentosum</td>
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<tr>
<td>Valpia fasciculata</td>
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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 gradi- 


teins, sediment mobility) that influence biogeographical patterns. This is in accordance with the 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 (R² = 0.741), as was also found for the islands of the S. Aegean (R² = 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 Acheloo 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.

**Acknowledgements**

This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program “Education and Lifelong Learning” of the National Strategic Reference Framework (NSRF) – Research Funding Program: Heraclitus II. Investing in knowledge society through the European Social Fund. In addition, the authors would like to thank two anonymous reviewers for their valuable comments on an earlier draft of this paper.

**References**


Appendix: Vascular plant catalogue

Symbols and abbreviations:

Life-form categories (following Dimopoulos & al. 2013): C = chamaephyte; H = hemicyryptophyte; 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 Meso-longi 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.

Asteraceae
Achillea maritima (L.) Ehrend. & Y. P. Guo – C, MA; ML1, ML2.
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 multiseta Sm. – T, EM; ML1.
Filago gallica L. – T, MA; ML2.
Glebionis segetum (L.) Fourr. – T, Me; AG5.
Hedypnois rhabadioides (L.) F. W. Schmidt – T, Me; AG1, AG2, AG4, AG5, ML1.
Hyoseris scabra L. – T, Me; AG1.
Hypocharis achyrophyllus L. – T, Me; AG1, AG2, AG3, AG4, AG5, ML1, ML2.
Limbara crithmoides (L.) Dumort. – C, MA; AG1, AG2, AG3, AG4, AG5, ML1, ML2, ML3, ML4.
Pulicaria odora (L.) Rchb. – H, Me; AG1.
Reichardia picoidea (L.) Roth – H, Me; AG1, AG2, AG3, AG4, ML1, ML2, ML3.
Scolymus hispanicus L. – H, ME; AG1, ML1, ML3.
Silphium marianum (L.) Gaertn. – H, Me; ML1.
Sonchus oleraceus L. – T, ME; AG1, AG3, ML3, ML4.

Boraginaceae
Alkanna tinctoria Tausch – H, Me; ML1, ML2.
Borago officinalis L. – T, Me; AG5.
Cerinthe 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; AG5.
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.

**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.) Besser – T, Pt; ML1.

**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.) Besser – T, Pt; ML1.

**Convolvulaceae**
Calystegia soldanella (L.) Roem. & Schult. – 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. serriata (Spreng.) Greuter – G, MS; AG1, AG2, AG5.
Cyperus capitatus Vand. – G, Me; ML2.
Scirpoides holoschoenus (L.) Soják – G, Pt; ML1, ML2, ML3, ML4.

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

**Ericaceae**

**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 peplus 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.
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 & Dörfl. – T, Me; AG5.
Tetragonolobus purpureus Moench – T, Me; AG5.
Trifolium angustifolium L. – T, EA; AG1, AG2, AG5, ML1, ML2, ML4.

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

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

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

**Ericaceae**

**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 peplus 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.
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 & Dörfl. – T, Me; AG5.
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; AG1, 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; AG1.

Hyacinthaceae
Drimia numidica (Jord. & Fourr.) J. C. Manning & Goldblatt – G, Me; AG2, ML1.
Muscaria 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 Broten – 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.
Sarapias vomeracea (Burm. f.) Briq. - G, ME; AG1.

Orobanchaceae
Orobanchec 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.
Bromus alopecuros Poir. – T, Me; AG1.
Bromus diandrus Roth – T, Me; ML1.
Bromus madritensis L. – T, ST; ML1, ML2.
Bromus rigidus Roth – T, ST; AG1, AG2, ML1.
Bromus rubens L. – T, MS; AG3, AG5.
Bromus squarrosum L. – T, Pt; ML2.
Bromus sterilis L. – T, MS; ML1, ML2, ML3.
Catabodium marinum (L.) C. E. Hubb. – T, MA; AG1, AG3, AG5, ML1, ML2, ML4.
Cynodon rigidum (L.) C. E. Hubb. – T, Me; AG1, AG3, AG5, ML1, ML2, ML4.

Digitaria sanguinalis (L.) Scop. – T, Co; AG5.
Elytrigia juncea (L.) Nevski – G, Me; AG1, AG2, AG3, AG4, AG5, ML1, ML2, ML3.
Festuca arundinacea Schreb. – H, Pt; ML2.
Gastridium ventricosum (Gouan) Schinz & Thell. – T, Me; AG1, AG2, AG3, AG4, AG5, ML1, ML2, ML3.
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.) P. Beauv. – T, Me; AG1, AG2, 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.
Piptatherum miliaceum (L.) Coss. – H, Me; AG1, ML1, ML2, ML3, ML4.
Puccinellia distans (L.) Parl. – H, Pt; AG1, ML1, ML2, ML4.
Puccinellia distans (L.) Parl. – H, Pt; AG1, ML1, ML2, ML4.
Rorippa nasturtioides (Gouan) Schrad. – T, Co; AG1, AG2, AG3.
Sporobolus pungens (Schreb.) Kunth – G, ST; AG1, AG2, AG3, AG4, AG5, ML1, ML2, ML3.

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 arvensis DC. – T, MS; ML1.
Ranunculus acris L. – H, Me; AG1.

Rhamnaceae

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.
Theiligeron 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, ES; ML1, ML3.

Smilacaceae
Smilax aspera L. – P, MA; AG1, AG2, AG3, AG4, AG5, AG6, ML1, ML2, ML4.

Solanaceae

Tamaricaceae
Tamarix halosperma Boiss. & Heldr. – P, EM; AG1, AG5, ML1, ML2, ML3, ML4.

Urticaceae
Urtica urens L. – T, Co; ML4.

Vitaceae
Vitis sp. – P; ML1.