Zotos A *et al.* (2021)
Notulae Botanicae Horti Agrobotanici Cluj-Napoca
Volume 49, Issue 3, Article number 12435
DOI:10.15835/nbha49312435
Research Article

Plant species diversity of the wet meadows under natural and anthropogenic interventions: The case of the Lakes Amvrakia and Ozeros (W. Greece)

Anastasios ZOTOS[1]*, Chariklia KOSMA[2], Vassilios TRIANTAFYLLIDIS[2], Ioanna KAKABOUKI[3], George KEHAYIAS[4], Ioannis ROUSSIS[3], Antonios MAVROEIDIS[3], Alexandros TATARIDAS[3], Dimitrios BILALIS[3]

[1]*University of Patras, Department of Biosystems and Agricultural Engineering, 30200 Messolonghi, Greece; azotos@upatras.gr (*corresponding author)*
[2]*University of Patras, Department of Biosystems Administration of Food and Agricultural Enterprises, 30100 Agrinio, Greece; xkosma@upatras.gr; vtrianta@upatras.gr*
[3]*Agricultural University of Athens, Department of Crop Science, Laboratory of Agronomy, 75 Iera Odos str., 11855 Athens, Greece; i.kakabouki@gmail.com; iroussis01@gmail.com; antoniosmauroeidis@gmail.com; a.tataridas@gmail.com; bilalisdimitrios@gmail.com*
[4]*University of Patras, Department of Food Science and Technology, 30100 Agrinio, Greece; gkechagi@upatras.gr*

Abstract

The Lakes Amvrakia and Ozeros (W. Greece) belong to the western chain of Greek wetlands running along the coast of the Ionian Sea. They are both natural lakes belonging to the Natura 2000, Site of Community Importance (pSCI) and are characterized by high ecological value. Wet meadows are typical habitat types of these wetland ecosystems which are in contact with rural ecosystems which they interact with. Due to the high conservation value of these habitat types, in the framework of this study the flora of the wet meadows was recorded and a floristic analysis concerning chorology, life forms and habitat preferences was made. A total number of 152 taxa was found in the wet meadows of both lakes from which only 47 taxa were common. The families with the greatest number of species were Fabaceae (22 taxa), Asteraceae (14 taxa) and Poaceae (9 taxa) for the wet meadow vegetation of the Lake Amvrakia and Fabaceae, Poaceae (17 and 13 taxa, respectively) for the Lake Ozeros. In both lakes the prevalence of the Therophytes is evident, while the life forms of Chamephytes and Aquatics were absent from the Lake Amvrakia. From the results of the canonical correspondence analysis among species, sampling plots and selected environmental variables, a clear separation between species and sampling plots was found, presenting strong correlation with specific edaphic parameters (pH, $CaCO_3$, EC, P_{Olsen}, Total N, SOC and NO_3^-). These edaphic properties, as a result of natural and anthropogenic interventions, seem to play an important role in the wet meadows plant species distribution pattern.

Keywords: land cover/use; soil properties; species richness; wet meadows; wetland

Received: 11 Jul 2021. Received in revised form: 16 Aug 2021. Accepted: 22 Aug 2021. Published online: 03 Sep 2021.
From Volume 49, Issue 1, 2021, Notulae Botanicae Horti Agrobotanici Cluj-Napoca journal uses article numbers in place of the traditional method of continuous pagination through the volume. The journal will continue to appear quarterly, as before, with four annual numbers.

Introduction

Wetlands in the Mediterranean basin are of particular importance from an ecological point of view. They support many animals and plant species of high conservation values while at the same time they offer the opportunity for numerous human activities. They also provide a unique habitat for many rare species whose development depends on the seasonal or permanent flooding. Land use changes coming from human activities cause a significant degradation of wetlands worldwide (Zorrilla-Miras *et al.*, 2014) affecting their structure and function and leading to their degradation (Galatowitsch *et al.*, 1998).

Nowadays one of the main impacts to the wetlands and consequently to the wet meadows is the drainage and the conversion of these areas to cultivated land, causing a disturbance on the functions of the ecosystems due to the intensive agriculture and the livestock presence. The consequent changes in land uses promote an increase in nutrient load causing at the same time a decrease in rare plants in the wetland communities (Ellenberg 1988; Moore *et al.*, 1989). In Greece, a severe degradation took place in Lake Stymfalia during the last decades due to agricultural activities in the surrounding areas (Papastergiadou *et al.*, 2007).

Ozeros and Amvrakia are two lakes with great ecological value belonging to the western chain of Greek wetlands and running along the coast of the Ionian Sea. Despite the fact that they are nearby, they present significant differences in their water depth, trophic state, seasonally water level fluctuation and land uses. At the Lake Amvrakia a significant part of the periodically flooded areas and wet meadows is lost every year and, in these areas, agricultural activities have been developed. In particular, in the northern part of the lake, this transformation has been particularly pronounced over the years. These land use changes in combination with the intensification of agriculture, signal the homogenization of the landscape leading to the reduction of plant species diversity (Lougheed *et al.*, 2008; Triantafyllidis *et al.*, 2020). In addition, land use changes affect the soil which is a constantly evolving system with spatial and temporal variation of its properties, affecting in turn the plant species distribution pattern. Previous, knowledge on the flora and the vegetation of the two examined lakes originates from Haláscy (1894, 1901-04), Bornmüller (1928), Koumpli-Sovantzi (1983) and Zervas *et al.* (2019), but they do not focus on the wet meadow species diversity. The aims of the present study were to: a) to record the plant species diversity in these two wet meadows, b) to compare the wet meadows plant species composition and the data concerning chorology, life form, status data and habitat preferences between the two lakes with different geomorphological characteristics and water status and c) to explore the impact of the different land uses between the two lakes and the influence of the main edaphic properties to the plant species richness.

Materials and Methods

Study area

Lake Amvrakia (38°45΄N, 21°10΄E) belongs to the European Ecological Network Natura 2000, Site of Community Importance (pSCI), GR 2310007. It is located 5 km North of the Lake Ozeros with a surface area of 14 km^2 and a maximum water depth of 50 m. Lake Amvrakia is a deep mesotrophic lake (Chalkia *et al.*, 2012), which belongs to the sulphate type, having the highest concentration of sulphates among the Greek lakes (Overbeck *et al.*, 1982; Zacharias *et al.*, 2002), which derive from extensive gypsum sediments especially in its western banks. The drainage area is about 112 km^2, and supplies the lake with water, while there are strong water level fluctuations due to high evaporation rates, especially during the summer, and the irrigation of the surrounding agricultural area. These variations usually result to the drainage of the shallower northern part of the basin in certain periods/years and, consequently, to the fluctuation of the surface area of the lake. The isolation of Lake Amvrakia from the other lakes of the region, along with the existing special physicochemical characteristics and geomorphology, has resulted to the presence of endemic species of phytoplankton (Danielidis *et al.*, 1996), and differences to the zooplankton community (Chalkia *et al.*, 2012).

Lake Ozeros (38 º 39 ' N, 21º 13 ' E) is a shallow lake with a maximum depth of 5.6m, a surface area of 10.1 km^2 and a closed drainage basin of 59 km^2 (Zacharias *et al*., 2002). It belongs to the European Ecological Network Natura 2000, Site of Community Importance (pSCI), GR 2310008, according to Directive 92/43/EEC. At the south-east side it is connected with the river Acheloos via a technical canal, through which the river overflows to the lake. Moreover, small torrents around the lake supply the lake with water. The significant amounts of fertilizers due to agricultural activity in combination with the waste of a large number of small livestock industries, have probably drove the lake to eutrophication with adverse effects on biodiversity (Chalkia and Kehayias, 2013).

Until 2006, the main cultivation around Lake Amvrakia was tobacco, which develops in low fertility soil in mountainous or semi-mountainous regions like the prefecture of Aetoloakarnania. However, the application of the Common Agricultural Policy (CAP) reform in relation to tobacco cultivation, resulted to an 80% reduction of the tobacco production in Greece and, specifically, 100% reduction in the prefecture of Aetoloakarnania. As a result, tobacco producers turned to other cultivations such as vegetables, olives, corn, aromatic plants and biological cultivations (Thomatou *et al*., 2013).

The differentiation of the two ecosystems in terms of land uses, in a zone of about 1 km from the shore, the Corine Land Cover database and the open-source QGIS version 3.12.3-București geographic information system (Quantum GIS Development Team, 2020) were used and the results are shown in Figure 2. In Lake Ozeros a distinct zone between the shore of the lake and the permanent irrigated areas was observed giving the taxa of the wet meadows the opportunity to develop. On the contrary in Lake Amvrakia the zone of inland marshes is absent, as the non-irrigated arable land expands to the shore of the lake, according to the Corine Land Cover data and field observations by the authors.

Data collection

In the framework of this research, the plant species of the wet meadows' vegetation zone in the Lakes Ozeros and Amvrakia were collected from April 2019 to October 2020 and the data concerning the presence/absence, life forms and habitat preferences were recorded. In particular, plant species diversity was recorded in sampling plots of 500 m^2, in places where wet meadows occurred around the lakes, seasonally flooded for about six to eight months (Figures 1 and 2).

During the collection of plant species, soil samples were taken in each sampling spot, using the zigzag soil sampling method.

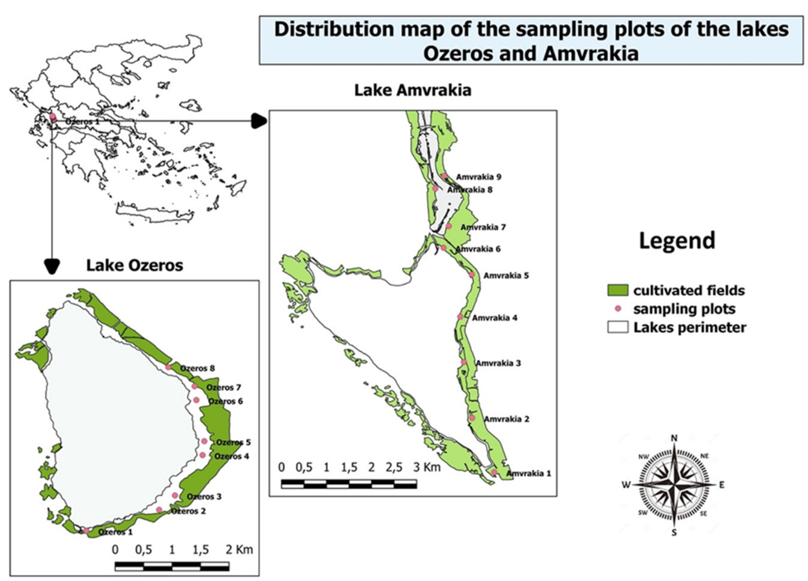

Figure 1. Distribution map of the sampling plots of the Lakes Ozeros and Amvrakia

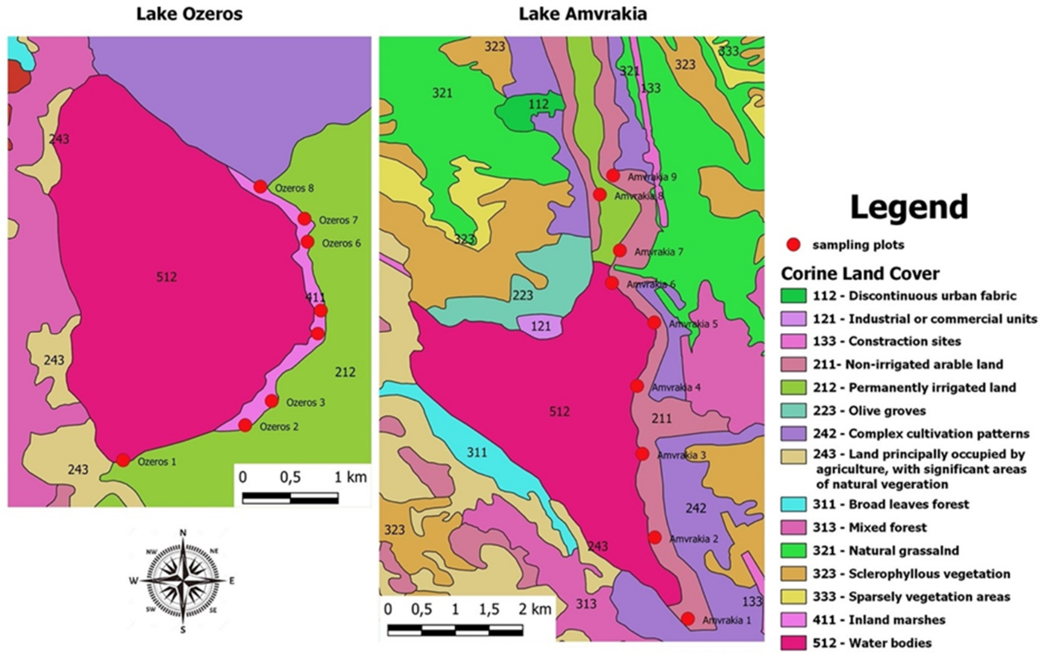

Figure 2. Distribution map of the sampling plots and the different land uses around the Lakes Ozeros and Amvrakia

[according Corine Land Cover database and the open-source QGIS version 3.12.3-București geographic information system (Quantum GIS Development Team, 2020)]

Data analysis

Plant specimens were identified mainly according to Tutin *et al.* (1968-80, 1993). Plant nomenclature follows Dimopoulos *et al.* (2013, 2016). Plant species are listed in alphabetical order in terms of Families, genera, species and subspecies into the major taxonomic groups. In addition, for each plant species data concerning of chorology, life form, status data and habitat preferences were used according to Dimopoulos *et al.* (2013, 2016). In total, five (5) main chorological elements (Widespread, Mediterranean, Greek endemic, Balkan and Allien) and 6 main life forms (Therophytes, Hemicryptophytes, Phanerophytes, Geophytes, Chamaephytes and Aquatic) were used in this study. Furthermore, five sub-categories were used for the classification of taxa in terms of habitat preferences (Freshwater habitats, Agricultural and ruderal habitats, Xeric Mediterranean phrygana and grasslands, Woodlands and scrub, Temperate and sub-Mediterranean grasslands).

Soil samples were air dried, then crushed and sieved through a 2-mm sieve. Particle size distribution was carried out using Bouyoucos's method (1962). The soil texture of samples was defined according to USDA particle-size classification diagram (Soil Science Division Staff, 2017). In saturated paste, electrical conductivity (EC) and soil pH (McLean, 1983; Rhoades, 1982) were measured. Total calcium carbonate ($CaCO_3$) equivalent was determined by using Bernard calcimeter. Soil organic matter (SOM) was determined by the method Walkley–Black (Nelson and Sommers, 1982), while SOM concentrations were converted to SOC as follows: SOC = SOM × 0.58 (Mann, 1986). Available P (P_{Olsen}) was measured according to Olsen (1954). The total N was estimated using the Kjeldahl method (Bremmer and Keeney, 1966) and in particular Kjeldahl distillation unit (model UKD 130 by Velp). The determination of NO_3^- was performed in 1:10 water-extracts. The extracted solutions of NO_3^- were analyzed by Dionex-1500 Ionic (Kosma *et al.*, 2009).

Statistical analysis

Canonical Correspondence Analysis (CCA) performed by the CANOCO software version 4.5 (ter Braak and Šmilauer, 1998) was used for exploratory data analysis and mainly to assess the effect of environmental factors on plant species distribution pattern. Monte Carlo significance test (499 random permutations) was used to assess the statistical significance of the relation between the plant species and the selected environmental variables. Step-wise analysis through forward selection was used to test the significance and strength of the explanatory variables of each variable group, holding each time one of them constant as covariates. Descriptive statistics were used to describe the soil properties. Non-parametric analysis of variance (Kruskal Wallis Test) was used to identify significant differences on soil properties between Amvrakia and Ozeros Lakes. Correlations among soil properties were determined using Spearman's rank correlation (Proc CORR, Spearman) procedure. Statistical analysis was carried out using the SPSS statistical package version 20.

Results

Flora

Field research on the wet meadows of the Lakes Ozeros and Amvrakia revealed a total number of 152 taxa from which one (1) was Pteridophyte and 151 were Spermatophyta belonging to Angiosperma. Plant species which were recorded in the wet meadows vegetation of both lakes belong to 102 genera and 35 families (Table 1). The number of taxa per family, is presented in Figure 3. The family with the highest number of species in Lake Ozeros was Fabaceae (17 taxa), followed by Poaceae (13 taxa) and Apiaceae, Asteraceae with 8 taxa each one. In the wet meadows of the Lake Amvrakia, Fabaceae was the richest family numbering 22 taxa, followed by Asteraceae (14 taxa) and Poaceae (9 taxa). From a floristic point of view, the wet meadows of Lake Ozeros were slightly richest since they include 103 taxa compared to Lake Amvrakia with 96 taxa, while 47 plant taxa were common in both areas. The above results were used in order to establish the similarity between the two lakes using the Sørensen similarity index. This index was preferred over others, as it gives greater weight to taxa that are common in the two ecosystems, rather than to taxa found in only one of them (Bobo *et al.*, 2006). The value of the similarity index determined is 0.47, showing that the two lakes do not present high similarity in terms of floristic diversity.

Table 1. Taxa collected in the wet meadows of the Lakes Amvrakia and Ozeros from April 2019 to October 2020, where (A1-A9 and O1-O8) and represent the sampling plots in which each taxon occurred and (–) = absence. In addition, data related to status (St), chorology (Chor.), Life-form (L.f), and habitat (H) preferences are also shown.

Families/Plant species	St		Chor.	L.f	H	Lakes	
						Amvrakia	Ozeros
PTERIDOPHYTA							
Equisetaceae							
Equisetum ramosissimum Desf.	N/N		W	G	F	A1, A2	-
SPERMATOPHYTA							
ANGIOSPERMA - DICOTYLEDONES							
Apiaceae							
Berula erecta (Huds.) Coville	N/N		W	G	F	-	O1
Daucus carota L. subsp. *carota*	N/N		W	H	Agr	A2	O1
Daucus guttatus Sm. subsp. *guttatus*	N/N		M	Th	X	A1	O1
Helosciadium nodiflorum (L.) W.D.J. Koch	N/N		W	Aq	F	-	O4, O5, O6, O7, O8
Hydrocotyle vulgaris L.	N/N		W	Aq	F	-	O3
Oenanthe pimpinelloides L.	N/N		W	H	F	-	O2, O3, O7
Oenanthe silaifolia M. Bieb.	N/N		W	H	F	-	O1, O4, O5, O6, O8
Tordylium apulum L.	N/N		M	Th	Agr	A1	-
Torilis arvensis (Huds.) Link	N/N		W	Th	Agr	A2, A5, A7	-
Torilis nodosa (L.) Gaertn.	N/N		W	Th	Agr	A1, A2, A3, A4	O6, O7

Families/Plant species	St		Chor.	L.f	H	Lakes	
						Amvrakia	Ozeros
Asteraceae							
Anthemis arvensis L.	N/N		W	Th	Agr	A5	O2, O3, O5
Anthemis austriaca Jacq.	N/N		W	Th	Agr	A2	-
Anthemis chia L.	N/N		M	Th	Agr	A9	-
Cichorium intybus L.	N/N		W	H	Agr	A6	O6, O8
Cirsium creticum (Lam.) d'Urv.	N/N		M	H	F	-	O1, O6, O7, O8
Crepis rubra L.	N/N		M	Th	T	A3, A4, A5	-
Crepis sancta (L.) Bornm.	N/N		W	Th	Agr	A1	-
Dittrichia viscosa (L.) Greuter	N/N		M	H	Agr	A3, A4, A7	O2, O3, O5
Erigeron bonariensis L.	Al		Al	H	Agr	A2	-
Filago eriocephala Guss.	N/N		M	Th	X	A7	-
Helminthotheca echioides (L.) Holub	N/N		M	Th	Agr	-	O3, O6
Matricaria recutita L.	N/N		W	Th	Agr	A2	-
Pulicaria dysenterica (L.) Bernh.	N/N		W	H	F	A5	O1, O3
Scolymus hispanicus L.	N/N		W	H	Agr	A6	-
Sonchus asper (L.) Hill	N/N		W	Th	F	A1	-
Symphyotrichum squamatum (Spreng.) G.L. Nesom	Al		Al	H	F	A5, A9	O1
Xanthium spinosum L.	Al		Al	Th	Agr	-	O6, O7, O8
Boraginaceae							
Cynoglossum columnae Ten.	N/N		M	Th	Agr	A1, A2, A9	-
Cynoglossum creticum Mill.	N/N		W	H	Agr	A3, A6	-
Echium plantagineum L.	N/N		W	Th	Agr	A8	O1, O2, O5, O7
Heliotropium halacsyi Riedl	N/R		G/E	Th	Agr	A2	-
Myosotis arvensis (L.) Hill	N/N		W	Th	Agr	A1, A2, A4	-
Myosotis ramosissima Rochel	N/N		W	Th	Agr	-	O2, O3, O8
Brassicaceae							
Capsella bursa-pastoris (L.) Medik.	N/N		W	Th	Agr	A1, A7	O1, O2
Hirschfeldia incana (L.) Lagr.-Foss.	N/N		W	Th	Agr	A1, A2, A3, A4, A5, A6, A9	-
Rapistrum rugosum (L.) All.	N/N		W	Th	Agr	A3	-
Rorippa sylvestris (L.) Besser	N/N		W	H	F	A1, A2, A3, A4, A5, A6,A7, A8, A9	O1, O2, O4
Campanulaceae							
Campanula ramosissima Sm.	N/N		M	Th	Agr	-	O3
Caryophyllaceae							
Arenaria serpyllifolia L.	N/N		W	Th	T	A1, A2, A3, A6	-
Cerastium glomeratum Thuill.	N/N		W	Th	Agr	-	O2
Petrorhagia prolifera (L.) P.W. Ball & Heywood	N/N		W	H	Agr	-	O6, O7
Polycarpon tetraphyllum (L.) L.	N/N		W	Th	Agr	-	O3
Silene gallica L	N/N		W	Th	Agr	-	O1
Silene nocturna L.	N/N		M	Th	Agr	A2, A4, A5, A7	-
Silene ungeri Fenzl	N/R		B	H	T	A6	-
Spergularia bocconei (Scheele) Graebn.	N/N		W	Th	Agr	A1	-
Convolvulaceae							
Calystegia sepium (L.) R. Br. subsp. *sepium*	N/N		W	H	F	-	O2, O4
Dipsacaceae							
Knautia integrifolia (L.) Bertol.	N/N		M	Th	Agr	-	O4, O5, O7, O8

Families/Plant species	St		Chor.	L.f	H	Lakes	
						Amvrakia	Ozeros
Euphorbiaceae							
Euphorbia helioscopia L.	N/N		W	Th	Agr	A1	-
Fabaceae							
Bituminaria bituminosa (L.) C.H. Stirt.	N/N		W	H	Agr	A3	O6, O8
Galega officinalis L.	N/N		W	H	Agr	A1, A4, A5, A6, A7, A9	-
Lathyrus sphaericus Retz.	N/N		W	Th	Agr	A3	O1
Lotus angustissimus L.	N/N		W	Th	F	A1, A4, A5, A7, A9	-
Lotus tenuis Willd.	N/N		W	H	F	A1, A8	O1, O2, O3, O5, O7, O8
Medicago lupulina L.	N/N		W	Th	Agr	-	O1
Medicago minima (L.) Bartal.	N/N		W	Ch	Agr	-	O3, O6, O7, O8
Medicago orbicularis (L.) Bartal.	N/N		W	Th	Agr	-	O6, O7
Medicago polymorpha L.	N/N		W	Th	Agr	A1, A2, A3, A4, A6	O2, O6, O8
Medicago rigidula (L.) All.	N/N		W	Th	Agr	A3, A9	-
Melilotus indicus (L.) All.	N/N		W	Th	F	A1, A2, A3, A5, A6, A7, A9	O1, O2, O3, O5
Trifolium angustifolium L.	N/N		W	Th	T	A3, A6. A9	-
Trifolium campestre Schreb.	N/N		W	Th	T	A2, A3, A6, A7, A8	O6, O7, O8
Trifolium fragiferum L.	N/N		W	H	F	A1	-
Trifolium nigrescens Viv.	N/N		M	Th	Agr	A2, 3, A7, A9	O1
Trifolium patens Schreb.	N/N		W	Th	F	A1, A2	-
Trifolium pratense L.	N/N		W	H	Agr	A4	-
Trifolium repens L.	N/N		W	H	F	A1, A4, A6	O1, O2, O3, O7, O8
Trifolium resupinatum L.	N/N		W	Th	Agr	A1, A2, A4	O1, O6, O7, O8
Trifolium scabrum L.	N/N		W	Th	T	A3, A5, A6, A7	O4, O6
Trifolium stellatum L.	N/N		M	Th	T	A1, A6	-
Trifolium tomentosum L.	N/N		M	Th	Agr	A1, A2, A3, A4, A6, A9	O1, O2, O5, O8
Trifolium vesiculosum Savi	N/N		W	Th	Agr	-	O2, O3
Trigonella corniculata (L.) L.	N/N		M	Th	Agr	A1, A3, A4, A5, A6, A7, A9	-
Vicia lutea L. subsp. *lutea*	N/N		M	Th	Agr	A4, A6, A7	O3, O5, O6, O8
Vicia villosa Roth subsp. *villosa*	N/N		W	Th	Agr	A3	O1, O3
Gentianaceae							
Blackstonia perfoliata (L.) Huds.	N/N		W	Th	F	-	O6, O7, O8
Geraniaceae							
Erodium cicutarium (L.) L'Hér.	N/N		W	Th	Agr	A1	-
Geranium brutium Gasp.	N/N		B	Th	F	A2	-
Geranium dissectum L.	N/N		W	Th	F	-	O4, O8
Geranium rotundifolium L.	N/N		W	Th	Agr	A1	-
Lamiaceae							
Calamintha nepeta (L.) Savi	N/N		W	H	Agr	A6	O2, O5
Lycopus europaeus L.	N/N		W	H	F	-	O2, O4, O6
Mentha aquatica L.	N/N		W	H	F	-	O1, O2, O3, O5
Mentha pulegium L.	N/N		M	H	F	A1, A2, A4, A6, A7, A9	O1, O2, O3, O4, O6,O7, O8
Mentha spicata subsp. *condensata* (Briq.) Greuter & Burdet	N/N		M	H	F	A1, A2, A3, A7	-
Prunella vulgaris L.	N/N		W	H	W/S	-	O1, O3, O5, O7
Stachys palustris L.	N/N		W	H	F	-	O2

Families/Plant species	**St**		**Chor.**	**L.f**	**H**	**Lakes**	
						Amvrakia	**Ozeros**
Teucrium scordium subsp. *scordioides* (Schreb.) Arcang.	N/N		W	H	F	A4	O4, O5
Lythraceae							
Lythrum hyssopifolia L.	N/N		W	Th	F	-	O2, O4, O5
Lythrum junceum Banks & Sol.	N/N		W	H	F	-	O1, O6, O7, O8
Lythrum salicaria L.	N/N		W	H	F	-	O2, O3, O4, O5
Malvaceae							
Malva sylvestris L.	N/N		W	H	Agr	A5, A6	-
Onagraceae							
Epilobium hirsutum L.	N/N		W	H	F	-	O1, O7, O8
Orobanchaceae							
Bellardia viscosa (L.) Fisch. & C.A. Mey.	N/N		W	Th	F	-	O1
Papaveraceae							
Papaver rhoeas L.	N/N		W	Th	Agr	A1, A3, A6	O2, O7
Plantaginaceae							
Plantago afra L.	N/N		M	Th	X	A2, A3, A9	-
Plantago lagopus L.	N/N		M	Th	Agr	A1, A2, A3, A4, A7, A8, A9	-
Plantago major L.	N/N		W	H	F	-	O1, O2, O3, O4, O5, O7, O8
Polygonaceae							
Polygonum aviculare L.	N/N		W	Th	F	A1	O2, O3, O8
Persicaria lapathifolia (L.) Delarbre	N/N		W	Th	F	A3, A7, A9	O2, O3, O5 O7
Rumex conglomeratus Murray	N/N		W	H	F	A4	O2, O3, O5, O6, O7, O8
Rumex crispus L.	N/N		W	H	F	-	O4
Rumex obtusifolius L.	N/N		W	H	F	A5	-
Rumex palustris Sm.	N/N		W	Th	F	A4, A5, A6, A7, A8	-
Portulacaceae							
Portulaca oleracea aggr.	N/N		W	Th	Agr	A3, A4, A5, A7, A9	O1, O2
Primulaceae							
Anagallis arvensis L.	N/N		W	Th	Agr	A1, A2, A3, A5	O1, O2, O3, O4, O5, O6, O7, O8
Asterolinon linum-stellatum (L.) Duby	N/N		M	Th	X	A1	O1
Ranunculaceae							
Ranunculus muricatus L.	N/N		W	Th	F	A2, A5	-
Ranunculus sardous Crantz	N/N		W	Th	F	-	O2, O3, O4, O5
Ranunculus trichophyllus Chaix	N/N		W	Th	F	A2, A6	-
Rosaceae							
Potentilla reptans L.	N/N		W	H	F	A1, A2, A5, A7, A8	-
Rubus sanctus Schreb.	N/N		W	P	W/S	-	O4, O6
Rubiaceae							
Galium debile Desv.	N/N		M	H	F	-	O1, O4, O5, O6, O7, O8
Galium elongatum C. Presl	N/N		W	H	F	-	O2, O3
Sherardia arvensis L.	N/N		W	Th	Agr	A1, A2	O2, O3
Solanaceae							
Datura stramonium L.	Al		Al	Th	Agr	-	O1, O5, O6, O7
Veronicaceae							
Veronica acinifolia L.	N/N		W	Th	Agr	-	O3, O5

Families/Plant species	**St**		**Chor.**	**L.f**	**H**	**Lakes**	
						Amvrakia	**Ozeros**
Veronica anagallis-aquatica L.	N/N		W	H	F	A1, A2	O4
Verbenaceae							
Phyla nodiflora (L.) Greene	N/N		W	H	F	A1, A2, A4, A7	O1, O4, O5, O6, O7, O8
Verbena officinalis L.	N/N		W	H	F	A1, A2, A3, A4, A5, A6, A7	O1, O3, O4, O5
Vitex agnus-castus L.	N/N		W	P	F	A1, A2, A3, A4, A5, A6, A7	O1, O2, O4, O6
	ANGIOSPERMA – MONOCOTYLEDONES						
Alismataceae							
Alisma plantago-aquatica L.	N/N		W	Aq	F	-	O4, O5,O8
Cyperaceae							
Carex distans L.	N/N		W	H	F	-	O1, O3, O7
Carex hirta L.	N/N		W	G	F	A1	O2
Carex otrubae Podp.	N/N		W	H	F	-	O1, O4, O5, O6
Cyperus fuscus L.	N/N		W	Th	F	A1, A2, A5, A6, A7, A8, A9	O2, O3, O4
Cyperus longus L.	N/N		W	G	F	-	O2, O3, O4, O5, O6, O7, O8
Scirpoides holoschoenus (L.) Soják	N/N		W	G	F	-	O2, O3, O4, O5, O8
Juncaceae							
Juncus bufonius L.	N/N		W	Th	F	A7, A9	-
Juncus fontanesii J. Gay	N/N		W	G	F	A1, A2, A9	O4
Juncus inflexus L.	N/N		W	G	F	-	O1, O4, O5, O6, O7
Orchidaceae							
Anacamptis laxiflora (Lam.) R.M. Bateman & al.	N/N		W	G	F	-	O2, O4, O8
Serapias vomeracea (Burm. f.) Briq.	N/N		W	G	X	-	O3
Poaceae							
Agrostis stolonifera L.	N/N		W	H	F	A1, A3	O2, O4, O5, O7, O8
Alopecurus myosuroides Huds.	N/N		W	Th	Agr	-	O2, O8
Alopecurus rendlei Eig	N/N		W	Th	F	-	O4, O5, O6, O7
Arundo plini L.	N/N		B	P	F	-	O1, O4, O7
Bromus madritensis L.	N/N		W	Th	Agr	A1	-
Cynodon dactylon (L.) Pers.	N/N		W	G	Agr	A3, A4	O3, O4, O5, O7
Digitaria sanguinalis (L.) Scop.	N/N		W	Th	Agr	-	O2, O4, O8
Echinochloa crus-galli (L.) P. Beauv.	N/N		W	Th	Agr	-	O4, O5, O6, O7, O8
Hordeum murinum L.	N/N		W	Th	Agr	A4	O2, O3, O8
Lolium perenne L.	N/N		W	H	Agr	A2	-
Paspalum distichum L.	Al		Al	G	F	-	O2, O3, O4, O5, O6, O7, O8
Phleum subulatum (Savi) Asch. & Graebn.	N/N		M	Th	X	A4	-
Phragmites australis (Cav.) Steud.	N/N		W	G	F	A2, A3, A4	O2, O3, O4, O6, O7, O8
Poa annua L.	N/N		W	Th	Agr	A1, A4	O2, O4, O5
Poa infirma L.	N/N		M	Th	Agr	A2	-
Poa trivialis L.	N/N		W	H	F	-	O2, O3, O4, O5, O6, O7
Setaria verticillata (L.) P. Beauv.	N/N		W	Th	Agr	-	O6, O8
Typhaceae							
Typha domingensis Pers.	N/N		W	G	F	-	O4

Abbreviations: in terms of status N/N: Native / Non Range-Restricted, Al: Alien / Established, N/R: Native / Range-Restricted, in terms of chorology Chorology Al: alien, W: widespread, B: Balkan, M: Mediterranean, G/E: Greek endemic, in terms of life-form Th: Therophyte, H: Hemicryptophyte, G: Geophyte, P: Phanerophyte, Aq: Aquatic, Ch: Chamaephyte, and in terms of Habitat preferences F: Freshwater habitats, Agr: Agricultural and Ruderal habitats, X: Xeric Mediterranean Phrygana and grasslands, W/S: Woodlands and scrub, T: Temperate and sub-Mediterranean Grasslands

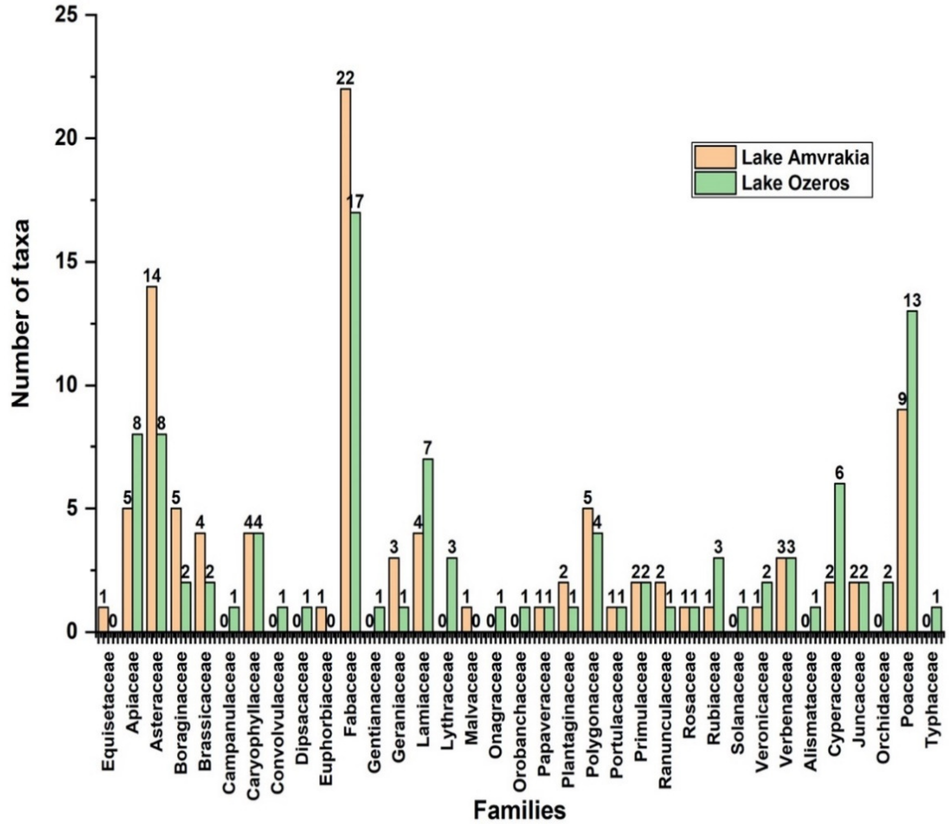

Figure 3. Number of taxa per family collected in the wet meadows of the Lakes Amvrakia and Ozeros from April 2019 to October 2020.

Considering the life forms, the prevalence of the Therophytes is evident in the wet meadows of both lakes followed by the Hemicryptophytes and Geophytes (Figure 4). The highest number of Therophyte species was recorded in Lake Amvrakia. The wet meadows of the Lake Ozeros presented higher number of taxa of the remaining life forms, while Chamephytes and Aquatics were not found in Lake Amvrakia.

A comparison of the biological spectrum (as the ratio of the life forms of species to the total number of species in both lakes) (Table 2), with the normal biological spectrum prepared by Raunkiaer is given in Figure 5. It is obvious that the Therophytes in both lakes present very high values compared with the values of the Raunkiaer's normal spectrum, while the corresponding difference in Hemicryptophytes is limited. In addition, the percentage composition of the Geophytes in the wet meadows of the Lake Amvrakia had the same value with the normal spectrum, in contrast with Lake Ozeros where the percentage of the Geophytes is twice as much. Finally, the percentage of the Phanerophytes and Chamephytes is very low in comparison with the Raunkiaer's normal spectrum revealing the low contribution of these life forms in both ecosystems.

Five chorological units were revealed and the total number of plant species in each one is shown in Figure 4. The only Greek endemic taxon (*Heliotropium halacsyi*) was recorded in Lake Amvrakia, while also 2 Balkan taxa (*Silene ungeri* and *Geranium brutium*) were observed. One (1) Balkan taxon (*Arundo plini*) was observed in Lake Ozeros, while two (2) and four (4) alien taxa were recorded in the Lakes Amvrakia and Ozeros, respectively. Despite their small participation in the two lakes, these invasive alien plant species prefer nutrient-rich and sunny sites presenting a threat to the diversity of native species (Zelnik, 2012; Perzanowska *et al.*, 2019).

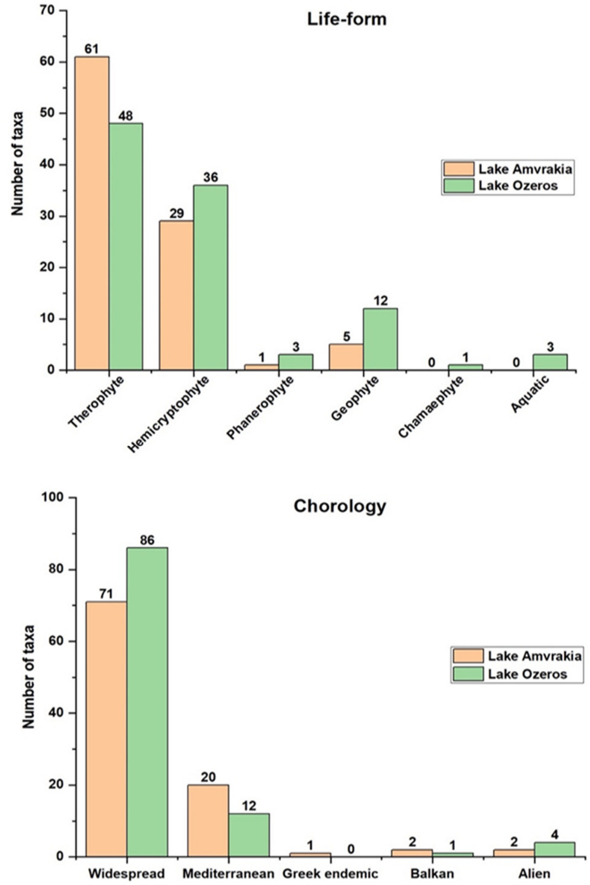

Figure 4. Life forms classification and chorology of taxa in the wet meadows of the Lakes Amvrakia and Ozeros

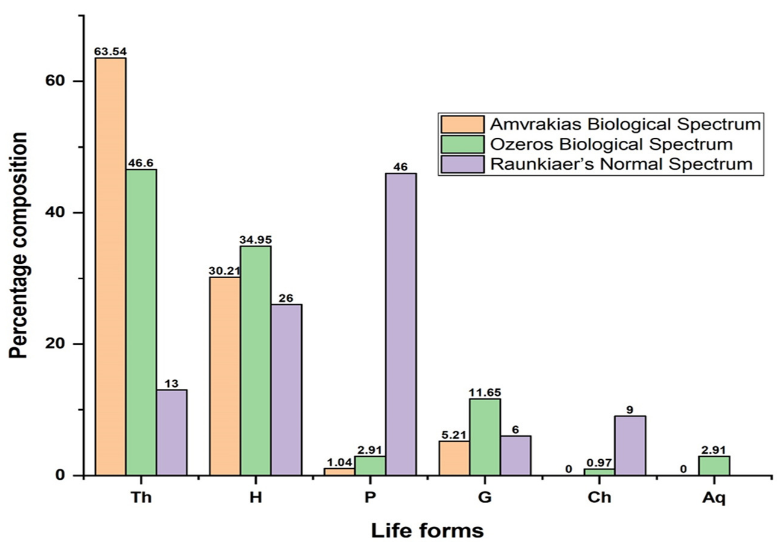

Figure 5. Percentage composition of life forms in the wet meadows of the Lakes Amvrakia and Ozeros
Life form groups: Th = Therophytes, H = Hemicryptophytes, P = Phanerophytes, G = Geophytes, Ch = Chamaephytes, Aq = Aquatic

Table 2. Life-form classification and biological spectrum of the wet meadows of the Lakes Amvrakia and Ozeros comparing with Raunkiaer's normal spectrum

Life form group	Number of species		Percentage composition (%)		Raunkiaer's Normal Spectrum (%)
	Amvrakia	Ozeros	Amvrakia	Ozeros	
Therophytes (Th)	61	48	63.54	46.60	13
Hemicryptophytes (H)	29	36	30.21	34.95	26
Phanerophyte (P)	1	3	1.04	2.91	46
Geophytes (G)	5	12	5.21	11.65	6
Chamaephytes (Ch)	-	1	-	0.97	9
Aquatic (Aq)	-	3	-	2.91	-
Total	96	103	100.00	100.00	100

The distribution of plant species of the wet meadows according to the habitat preferences revealed that in the Lake Ozeros the taxa of the freshwater habitats were the most common followed by those of agricultural and ruderal habitats with 54 and 42 taxa, respectively. The opposite was recorded in Lake Amvrakia where the taxa of the agricultural and ruderal habitats were 51, followed by 33 taxa which were common in freshwater habitats (Figure 6).

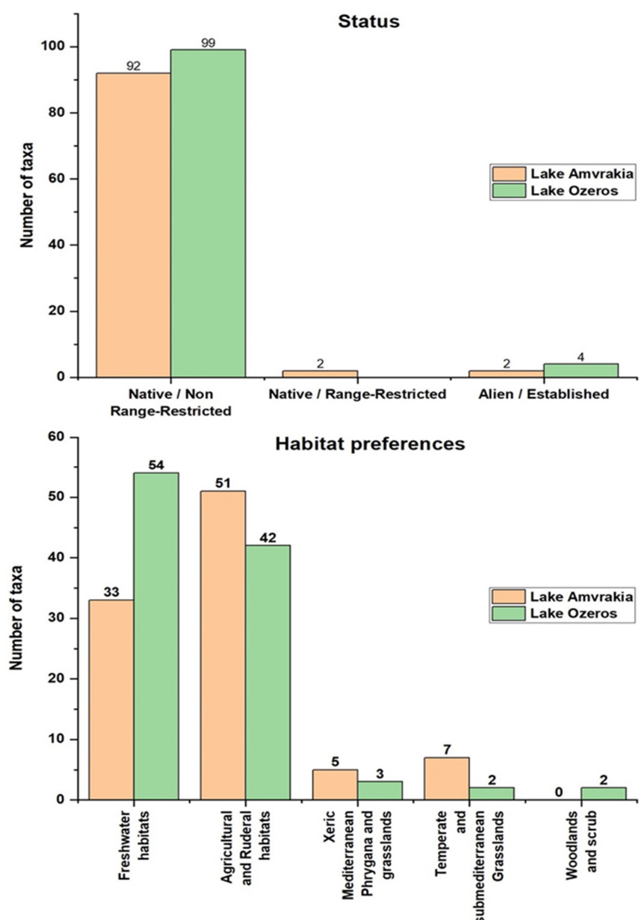

Figure 6. Conservation status and habitat preferences of taxa in the wet meadows of the Lakes Amvrakia and Ozeros

Edaphic properties

Except for the clay content which presents higher mean values in the wet meadows of the Lake Ozeros compared to Lake Amvrakia, no significant differences were observed in the soil properties between the two lakes (Table 3). However, a wide range of values (e.g., pH values from 6.2 to 8.2, P_{Olsen} concentrations from 11.0 to 42.8 mg kg^{-1}) was observed for all soil properties (Table 3), showing a high spatial variability of these elements in the study area. Spearman correlation of the soil properties in the study area among correlated variables (Table 4) showed that the concentrations of the nitrates (NO_3-N) present significant positive correlation (p <0.01) with soil EC values, while the concentrations of the available phosphorus (P_{Olsen}) were negative correlated (p <0.01) with the $CaCO_3$ and the soil pH values.

Table 3. Soil fertility status of agricultural land across the perimeter on Ozeros and Amvrakia lakes, Western Greece

	Ozeros lake			Amvrakia lake			Total study area
Edaphic properties	min	mean± S.D.	max	min	mean±	max	
pH	6.20	7.10±0.43	8.10	6.30	7.14±0.71	8.20	7.11±0.57
EC dS m^{-1}	0.14	0.89±0.49	2.47	0.30	0.93±0.33	1.68	0.91±0.42
Sand (%)	23.5	36.3±6.10	46.2	26.5	37.8±8.96	46.0	37.0±5.60
Silt (%)	21.6	34.6±4.89	40.7	22.6	35.3±4.18	41.0	34.9±4.58
Clay (%)	22.0	29.2±4.89*	39.0	18.0	26.4±5.18*	38.4	28.0±5.17
Total $CaCO_3$ (%)	0.10	3.34±3.52	9.28	0.00	4.73±5.70	16.4	3.94±4.61
SOC (g kg^{-1})	3.25	11.6±3.58	22.2	1.62	10.2±2.66	14.2	11.0±3.26
Total N (g kg^{-1})	0.71	1.16±0.28	1.79	0.73	1.12±0.29	1.76	1.14±0.28
NO_3 −	7.30	10.6±2.26	18.5	6.70	11.0±2.23	17.0	10.8±2.24
P_{Olsen} (mg kg^{-1})	11.0	18.5±5.09	30.8	7.25	19.1±8.44	42.8	18.7±6.71

* Indicates significant differences at significance level P<0.05 between values in rows for each parameter between lakes.

Table 4. Spearman correlations among soil properties of total study area (S_{total})

	pH	EC	Sand	Silt	Clay	Total $CaCO_3$	SOC	Total N	NO_3	P_{Olsen}
pH	1.00									
EC	-0.07	1.00								
Sand	0.03	-0.24	1.00							
Silt	-	0.20	-.520**	1.00						
Clay	.486**	0.15	-.485**	-.331**	1.00					
Total $CaCO_3$	.897**	0.03	-0.01	-.361**	.363**	1.00				
SOC	.346**	0.11	-0.07	-0.21	.450**	.260*	1.00			
Total N	-.270*	0.13	-0.16	.347**	0.05	-.244*	0.17	1.00		
NO_3 − N	-0.11	.538**	-.342**	.264*	0.20	-0.02	0.07	0.09	1.00	
P_{Olsen}	-	0.02	0.15	0.13	-.394**	-.709**	-.352**	0.08	-0.08	1.00

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

Ordination

In order to reveal the main edaphic parameters which, influence the development of the taxa in the wet meadows vegetation in each lake, the results of the soil analysis were correlated with the plant species presence/absence data using the Canonical Correspondence Analysis (CCA). The results of the CCA analysis among taxa, sampling plots and environmental variables are shown in CCA biplots (Figures 7 and 8). Table 5 shows that axes 1 and 2 represent the greatest amount of explanatory values (42 and 29%, respectively). CCA analysis of the sampling plots, species and environmental variables based on the first two axes, explains the 22.1% of the variance (inertia) of species data and the 34.3% of the variance in the weighted averages of the species with respect to the environmental variables (Table 5).

The environmental variables in the biplot graphs are represented by arrows, the length of which is proportional to the rate of change into the direction of the maximum change of these variables across the diagram (ter Braak, 1987). Among these environmental variables, the longest arrows are represented by NO_3-N, Total N, $CaCO_3$ and pH, followed by those of P_{Olsen}, sand, SOC, EC and clay (axis 1: Sand, SOC, Clay and Total N and axis 2: Nitrate, pH, EC and $CaCO_3$).

Along axis 1 the 39%, 32%, and 30% of the species composition are explained by the Total N, sand and SOC respectively while the clay explains a lower (24%) percentage (Table 5). In addition, along axis 2, the 55% and 48% of the species composition are explained by the $CaCO_3$ and pH, respectively, followed by other variables such as NO_3-N, P_{Olsen}, and EC which explain the 40%, 33% and 18%, respectively (Table 5).

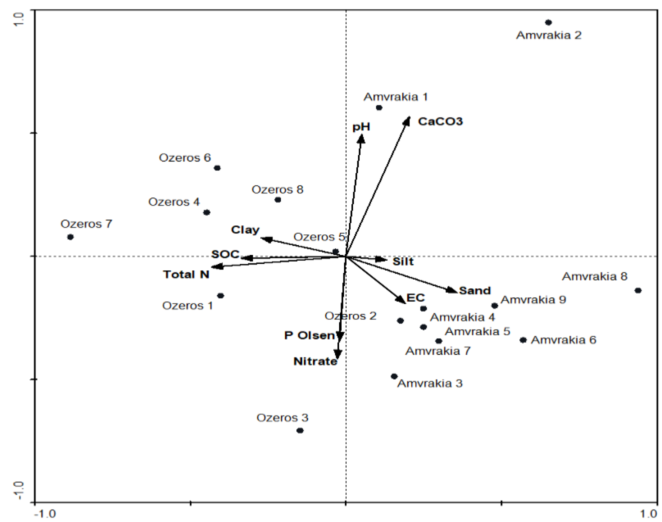

Figure 7. CCA ordination diagram with sampling plots (bullets) and environmental variables (pH, EC, Sand, Silt, Clay, $CaCO_3$-, SOC, Total N, Nitrate, P_{Olsen}) (arrows)

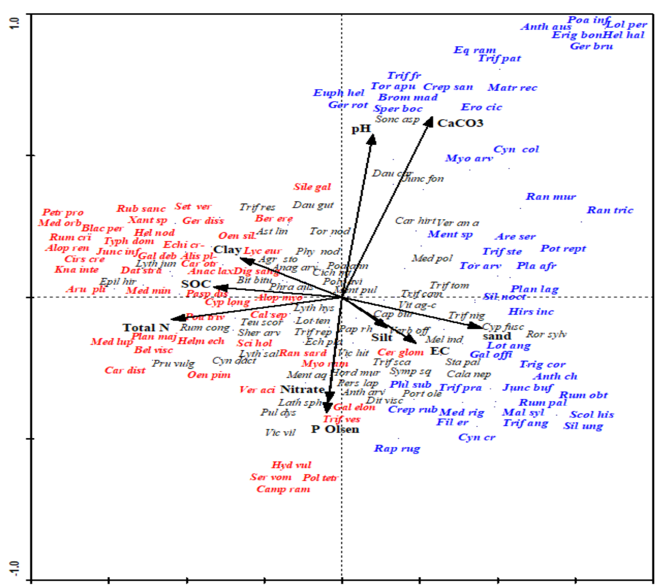

Figure 8. CCA ordination diagram with taxa (bullets) and environmental variables (pH, EC, Sand, Silt, Clay, $CaCO_3$-, SOC, Total N, Nitrate, P_{Olsen}) (arrows)
Explanations: Full names of taxa are given in Table 1.

Table 5. Correlations of environmental variables (pH, EC, Sand, Silt, Clay, $CaCO_3$-, SOC, Total N, Nitrate, P_{Olsen}) with the first two CCA axes

Environmental variables		Axis 1	Axis 2
pH		0.04	0.48
EC		0.17	-0.18
Sand		0.32	-0.14
Silt		0.11	-0.01
Clay		-0.24	0.07
$CaCO_3$		0.18	0.55
SOC		-0.30	-0.01
Total N		-0.39	-0.04
Nitrate		-0.02	-0.40
P_{Olsen}		-0.01	-0.33
Eigenvalues		0.42	0.29
Species-environment correlation		0.90	0.98
Cumulative percentage variance:			
(i) of species data		13.0	22.1
(ii) of species-environment relation		20.2	34.3
Total inertia:	3.225		
Sum of all eigenvalues:	3.225		
Sum of all canonical eigenvalues:	2.095		

Eigenvalues of the ordination axes and sum of all unconstrained Eigenvalues (total inertia) for CCA analysis.

The CCA biplot ordination diagrams between sampling plots and environmental variables reveal a clear distribution among sampling plots in the two lakes (Figure 7). Almost all the sampling plots in Lake Ozeros are grouped mainly in the left part of the diagram strongly correlated with the Total N, SOC and clay. An exception is observed in Ozeros 2 and Ozeros 3 plots which seem to be correlated, the first one with the electric conductivity (EC) while the second one (Ozeros 3) is strongly correlated with the soil nitrates (NO_3-N), and the available phosphorus (P_{Olsen}). The rest of the sampling plots in Lake Amvrakia are grouped in the right part of the diagram creating two distinct subgroups. The first one is located in the upper right part of the diagram strongly correlated with the soil pH and the $CaCO_3$ content, while the other group is located in the bottom right part of the ordination diagram correlated mainly with the soil electric conductivity and the sand content.

From the second CCA biplot ordination diagram between species and environmental variables a clear distribution among species which appeared in only one of the two examined lakes was observed (Figure 8). On the left part of the ordination diagram the species which were identified in the wet meadows of the Lake Ozeros were grouped, presenting a strong correlation with Total N, SOC, clay, NO_3-N and P_{Olsen}. In contrast, taxa which were identified only in the wet meadows of the Lake Amvrakia were grouped on the right part of the diagram and they present a strong correlation with soil pH, $CaCO_3$, sand, silt, and EC. The rest of the species which were identified in the wet meadows of both lakes show a random distribution within the ordination diagram.

Discussion

The Lakes Amvrakia and Ozeros belong to the European Ecological Network Natura 2000 Site of Community Importance (pSCI) and, despite the fact that they are close to each other, they present significant differences in the geomorphological features (Zacharias *et al.*, 2002), in the water physico-chemical characteristics (Chalkia *et al.*, 2012; Chalkia and Kehayias, 2013), and finally in the trophic status. Based on natural interventions (dominant identifiers) the prevailing soil groups in both study areas are: Fluvisols (FV), Luvisols (LV), Cambisols (CM) and Calcisols (CL), according to European Soil Data Centre (ESDAC) and the National Soil Maps (EUDASM, 2015). Soil element content in most cases depends on the geochemical composition of the weathering rock parent material on which the soil has been developed. Rodeghiero *et al.* (2011) report that the Mediterranean soils present a high spatial variability in their properties, reinforcing the need of a careful consideration of soil groups when conducting a soil survey. Our results showed high spatial variability of the soil properties (Table 3), attributed both to anthropogenic (different land use, followed by different agriculture practices) and natural interventions (such as the prevailing soil groups FV, LV, CM, CL). The exposure of plant species into these mixed interventions seems to affect their composition.

The results of this study revealed a total number of 152 taxa belonging to 35 families and 102 genera, from which only 47 were common. The families Fabaceae, Asteraceae and Poaceae, Cyperaceae from the dicotyledones and monocotyledons, respectively, are the richest, since they present the greatest number of plant species, which is in accordance with other studies which took place in natural lakes (Koumpli-Sovantzi, 1983; Pavlidis, 1985; Papastergiadou, 1990; Sarika-Hatzinikolaou, 1999; Zotos, 2006). The high percentage of the Mediterranean taxa in combination to the predominance of Therophytes in the wet meadows vegetation of both lakes can confirm the Mediterranean character of the flora of the Lakes Ozeros and Amvrakia. Moreover, the high percentage of the Therophytes in Lake Amvrakia, as well as their 20% lower percentage in Lake Ozeros, indicate the disturbance of the wet meadows vegetation as a result of intensive anthropogenic and livestock impact on these sites (Cain, 1950; Smith, 1980). Panitsa *et al.* (2008), reported that the Therophyte life form is linked to disturbances in Mediterranean ecosystems. Therophytes are annual plants which can survive the unfavorable dry and cold seasons as seeds, achieving better adaptability to adverse growing conditions. Empirical data, collected originally by Raunkiaer (1934) and reinforced by more recent studies, suggest a greater tendency of annual species to flourish in seasonally dry than in arid environments. Blumler (2018) reported that Therophytes tended to occur in sites with warmer and drier conditions, and therefore the arable soils which occurred in Lake Amvrakia offer favorable conditions for these species to develop compared to Lake Ozeros where different land uses occur.

In addition, the remarkable small percentage of Phanerophytes, in combination with the dominance of Therophytes in the wet meadows of both lakes is an indicator of the degradation due to intense anthropogenic interventions. The lower percentage of taxa belong to the Hemicryptophytes, can be attributed mainly to the weak temperate character of the investigated area (Raunkiaer, 1934). The percentage composition of the Geophytes in Lake Amvrakia presents the same value with the normal spectrum, in contrast with Lake Ozeros where the percentage of the Geophytes is twice as much. Lazarina *et al.* (2019) observed that the Geophytes occurred in sites with significantly higher precipitation, or under wet conditions. In the study area the inland marshes zone which occurs in Lake Ozeros promotes the survival of Geophytes compared to the non-irrigated arable land zone of Lake Amvrakia. This observation reinforces the view that, under the same microclimate context which occurs in the two neighboring ecosystems in the study area, with additionally different natural or anthropogenic interventions, Therophytes and Geophytes have different growing behavior. However, in the study area Geophytes were absent from the sampling sites A6, A7 and A8 probably due to the slight acid soil reaction. In these sampling plots significant differences were observed in pH values in comparison with all other sampling plots either in Amvrakia or in Ozeros area except for the A5 and A9 plots. The lowest mean value with S.D. was observed in A8 (6.27±0.6), followed by A7 (6.47±0.6), A6 (6.50±0.00), A9 (6.53±0.12) and A5 (6.57±0.6), while the highest mean values observed in A1 (8.02±0.22) and A2 (7.88±0.21), mainly due to different soil groups (CM and CL, respectively) in this lake or due to anthropogenic interventions. In Lake Ozeros the mean pH values ranged from 6.63±0.25 (O4) to 7.50±0.35 (O2) revealing a lower spatial soil pH variability due to the higher number of different prevailing soil groups which occur (FV, LV and CM). Our results showed that the acid soil reaction (pH) is unfavorable for Geophytes composition, which is in accordance with Chytrý *et al.* (2010), who reported that this may be a result of the evolution of this group on base-rich dry soils in the Mediterranean climate.

The predominance of taxa which prefer agricultural and ruderal habitats instead of those which prefer freshwater habitats in the wet meadows of the Lake Amvrakia, reveals the influence of the anthropogenic activities into the plant species diversity, as a result of the intensive agricultural practices mainly due to the drainage of the northern part of the lake and the nearby urban ecosystems. High percentage of ruderal species in areas with intensive human activity, as well as in naturally nutrient rich and disturbed habitats have been described in other studies (Nilsson *et al.*, 1989; Dimopoulos *et al.*, 2013). In addition, the pressure that takes place due to the intensive grazing in Lake Amvrakia, as well as the expansion of cultivated areas, in several cases up to the shore of the lake (Figure 2) and the growing urbanization lead to the increase of ruderal species, decreasing at the same time the plant richness (Pyšek *et al.*, 2004; McKinney, 2006). On the contrary, in the wet meadows of the Lake Ozeros, taxa which prefer the freshwater habitats represent the highest percentage followed by those which prefer the agricultural and ruderal habitats, indicating the lower impact of human activities and the nearby urban ecosystems on this lake.

The above could also explain the predominance of taxa which prefer freshwater habitats instead of those which prefer agricultural and ruderal habitat in Lake Ozeros. Finally, the predominance of plant species of ruderal and freshwater habitats in both lakes can interpret the high proportion of widespread and non-native taxa, as well as the very low presence of endemic species (Dimopoulos *et al.*, 2013).

The soil analysis reveals significant differences regarding the ecological conditions in which the plant species were developed. In Lake Amvrakia a positive correlation of soil pH and the sampling plots (A1 and A2) which present a greater plant richness was observed. This positive correlation between soil pH and plant species richness (especially on annual species) has been revealed in many studies (Chytrý *et al.,* 2003; Schuster and Diekmann, 2003). In contrast, the availability of the phosphorus seems to have negative impact on species richness as the rest of the sampling plots at the same lake present significant lower plant species richness, which is in accordance with other studies (Zelnik and Čarni, 2013; Soons *et al.*, 2017). The results show that this P availability can be attribute to mixed interventions (e.g., the acid soil reaction (pH) which characterizes Cambisols increases the P available, as shown in Table 4, while the application of P fertilizers is an additional input source of phosphorus). Moreover, the high-water level fluctuation which is observed in Lake Amvrakia, due to increased evaporation in the summer and to the over-consumption of water for irrigation, lead almost every year to the drainage of the northern part of the lake at that time. The above, in combination with the installation of annual crops and the wide use of nitrogen fertilizers, lead to the accumulation of nitrate with a negative impact on plant species richness. After all, the decrease of plant species richness in association with a high concentration of nitrates have been described by Gough *et al.* (2000).

In the wet meadows of the Lake Ozeros, most of the sampling plots (except O2 and O3), present positive correlation with clay, SOC and Total N. The higher species richness which occurs in these plots can influence the topsoil organic carbon (Fischer *et al.*, 2019), while the simultaneous increase of nitrogen deposits in these soils can lead to the reduction of plant species richness (Stevens *et al.*, 2004). On the contrary, from the O2 and O3 sampling plots on the left and the right side of the canal which connects the lake with the river Acheloos, a strong correlation primarily with the available phosphorus (P_{Olsen}), nitrates and secondarily with the EC was observed. The high concentrations of the available phosphorus (P_{Olsen}) in combination with the high concentrations of soil nitrates which observed in these sampling plots, can influence the plant species composition of the wet meadows. Indeed, the gradual increase of the nitrates affects the species richness of the wet meadows in shallow lakes (James *et al.*, 2005). In addition, the large number of small livestock facilities around Lake Ozeros and the intensive grazing are the main limiting factors which influence the plant species richness.

Conclusions

The knowledge about the species diversity of the wet meadows in the Lakes Amvrakia and Ozeros, in combination with their inclusion in the Hellenic NATURA 2000 network, can be a useful tool for their conservation through the application of rational management measures. Changes to the land use seem to affect the plant species distribution pattern in both lakes. The prevalence of Therophytes and at the same time the low participation of Phanerophytes is an indicator of the degradation of the wet meadows, due to the intense anthropogenic interventions. This seems to be higher in the Lake Amvrakia due to the expansion of the cultivated fields and the intense drainage which took place almost every year in the northern part of the lake. On the contrary, the predominance of taxa which prefer the freshwater habitats in Lake Ozeros, instead of those which prefer agricultural and ruderal habitats, explain the lower degradation in this ecosystem. The different land uses which take place in the two lakes in combination with the formation of an inland marshes zone in Lake Ozeros give the opportunity to many emergent plant species such as *Phragmites* sp., *Juncus* sp., *Cyperus* sp., *Scirpus* sp. to develop in this lake. In addition, soil properties such as soil pH, NO_3-N, P_{Olsen}, EC, $CaCO_3$ and SOC seem to play an important role in the wet meadows plant species distribution pattern and therefore should be taken into consideration in order to design an integrated management plan. Finally, the knowledge of the current situation in terms of plant species diversity in conjunction with the optimal recording of pressures and threats due to the extensive land use changes, could be a useful guide to implement more targeted management plans in both lakes.

Authors' Contributions

Conceptualization: AZ; Data curation: AZ, CK, VT, IK and GK; Formal analysis: AZ, CK, VT, GK; Investigation: AZ, CK, VT, IK, GK, IR, AM, AT and DB; Methodology: AZ, CK, VT, GK; Project administration: AZ; Resources: AZ, CK, VT, IK, GK, IR, AM, AT and DB; Supervision: AZ and VT; Validation: AZ, CK, VT, IK, GK, IR, AM, AT and DB; Visualization: AZ; Writing-original draft: AZ, CK and VT; Writing-review and editing: AZ, CK, VT, IK, GK, IR, AM, AT and DB. All authors read and approved the final manuscript.

Acknowledgements

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

References

Blumler MA (2018). What is the 'true' Mediterranean-type vegetation? In: Greller AM, Fujiwara K, Pedrotti F (Eds). Geographical Changes in Vegetation and Plant Functional Types. Springer International Publishing, Cham pp 117-139. *https://doi.org/10.1007/978-3-319-68738-4_6*

Bobo KS, Waltert M, Moses Sainge N, Njokagbor J, Fermon H, Mühlenberg M (2006). From forest to farmland: Species richness patterns of trees and understory plants along a gradient of forest conversion in Southwestern Cameroon. Biodiversity & Conservation 15:4097-4117. *https://doi.org/10.1007/s10531-005-3368-6*

Bouyoucos GJ (1962). Hydrometer method improved for making particle size analyses of soils 1. Agronomy Journal 54(5):464-465.

Bornmüller J (1928). Ergebnis einer botanischen Reise nach Griechenland im Jahre 1926 (Zante, Cephallonia, Achaia, Phokis, Aetolien) [Results of a botanical voyage to Greece in the year 1926 (Zante, Cephallonia, Achaia, Phokis, Aetolia)]. Repertorium Specierum Novarum Regni Vegetabilis 25:161-203 & 270-350.

Bremmer JM, Keeney DR (1966). Exchangeable ammonium, nitrate, and nitrite by extraction–distillation methods. Soil Science Society of American Proceedings 30:577-582.

Cain SA (1950). Life-form and phytoclimates. Botanical Review 16(1):1-32.

Chalkia E, Kehayias G (2013). Zooplankton community dynamics and environmental factors in Lake Ozeros (Greece). Mediterranean Marine Science 14(3):32-41. *https://doi.org/10.12681/mms.534*

Chalkia E, Zacharias I, Thomatou A-A, Kehayias G (2012). Zooplankton dynamics in a gypsum karst lake and interrelation with the abiotic environment. Biologia 67:151-163. *https://doi.org/10.2478/s11756-011-0147-6*

Chytrý M, Tichý L, Roleček J (2003). Local and regional patterns of species richness in Central European vegetation types along the pH/calcium gradient. Folia Geobotanica 38(4): 429-442. *https://doi.org/10.1007/BF02803250*

Chytrý M, Danihelka J, Axmanová I, Božková J, Hettenbergerová E, Li, CF, … Zelený D (2010). Floristic diversity of an eastern Mediterranean dwarf shrubland: the importance of soil pH. Journal of Vegetation Science 21(6):1125-1137.

Cong WF, van Ruijven J, Mommer L, De Deyn GB, Berendse F, Hoffland E (2014). Plant species richness promotes soil carbon and nitrogen stocks in grasslands without legumes. Journal of Ecology 102(5):1163-1170. *https://doi.org/10.1111/1365-2745.12280*

Danielidis DB, Spartinou M, Economou-Amilli A (1996). Limnological survey of Lake Amvrakia, western Greece. Hydrobiologia 318(3):207-218.

Dimopoulos P, Raus T, Bergmeier E, Constantinidis T, Iatrou G, Kokkini S, … Tzanoudakis D (2013). Vascular plants of Greece: An annotated checklist. Botanic Garden and Botanical Museum Berlin, Dahlem, Berlin; Hellenic Botanical Society, Athens.

Dimopoulos P, Raus T, Bergmeier E, Constantinidis T, Iatrou G, Kokkini S, Tzanoudakis D (2016). Vascular plants of Greece: An annotated checklist. Supplement. Willdenowia 46(3):301-347. *https://doi.org/10.3372/wi.46.46303*

Ellenberg HH (1988). Vegetation ecology of central Europe. Cambridge University Press.

European Digital Archive of Soil Maps (EUDASM) (2015). Soil Map of Greece, Publisher by OPEKEPE and Aristotle University of Thessaloniki.

Fischer C, Leimer S, Roscher C, Ravenek J, de Kroon H, Kreutziger Y, … Hildebrandt A (2019). Plant species richness and functional groups have different effects on soil water content in a decade-long grassland experiment. Journal of Ecology 107(1):127-141. *https://doi.org/10.1111/1365-2745.13046*

Galatowitsch SM, Whited DC, Tester JR (1998). Development of community metrics to evaluate recovery of Minnesota wetlands. Journal of Aquatic Ecosystem Stress and Recovery 6(3):217-234.

Gough L, Osenberg CW, Gross KL, Collins SL (2000). Fertilization effects on species density and primary productivity in herbaceous plant communities. Oikos 89(3):428-439. *https://doi.org/10.1034/j.1600-0706.2000.890302.x*

James C, Fisher J, Russell V, Collings S, Moss B (2005). Nitrate availability and hydrophyte species richness in shallow lakes. Freshwater Biology 50(6):1049-1063. *https://doi.org/10.1111/j.1365-2427.2005.01375.x*

Halácsy E. von (1894). Beitrag zur Flora von Aetolien und Acarnanien [Contribution to the flora of Aetolia and Acarnania]. Denkschriften der Kaiserlichen Akademie der Wissenschaften / Mathematisch-Naturwissenschaftliche Classe 61:309-322.

Halácsy E von (1901-1904). Conspectus florae Graecae (1-3). Lipsiae.

Koumpli-Sovantzi L (1983). Studies on the Tracheophytes in the lakes and adjacent hydrobiotopes of Aetoloakarnania, Greece. Taxonomic, floristic, phytogeographical and ecological research. PhD thesis, University of Athens. [in Greek]

Kosma C, Balomenou G, Salahas G, Deligiannakis Y (2009). Electrolyte ion effects on Cd_{2+} binding at Al_2O_3 surface: Specific synergism versus bulk effects. Journal of Colloid and Interface Science 331(2):263-274.

Lazarina M, Charalampopoulos A, Psaralexi M, Krigas N, Michailidou DE, Kallimanis AS, Sgardelis SP (2019). Diversity patterns of different life forms of plants along an elevational gradient in Crete, Greece. Diversity 11(10):200. *https://doi.org/10.3390/d11100200*

Lougheed VL, McIntosh MD, Parker CA, Stevenson RJ (2008). Wetland degradation leads to homogenization of the biota at local and landscape scales. Freshwater Biology 53(12):2402-2413. *https://doi.org/10.1111/j.1365-2427.2008.02064.x*

McKinney ML (2006). Urbanization as a major cause of biotic homogenization. Biological Conservation 127(3):247-260. *https://doi.org/10.1016/j.biocon.2005.09.005*

Mann LK (1986). Changes in soil carbon storage after cultivation. Soil Science 142: 279-288.

McLean EO (1983). Soil pH and lime requirement. Methods of soil analysis: Part 2 Chemical and Microbiological Properties 9:199-224.

Moore DR, Keddy PA, Gaudet CL, Wisheu IC (1989). Conservation of wetlands: do infertile wetlands deserve a higher priority? Biological Conservation 47(3):203-217.

Nelson DW, Sommers L (1982). Total carbon, organic carbon, and organic matter 1. Methods of soil analysis. Part 2. Chemical and Microbiological Properties 539-579.

Nilsson C, Grelsson G, Johansson M, Sperens U (1989). Patterns of plant species richness along riverbanks. Ecology 70(1):77-84. *https://doi.org/10.2307/1938414*

Olsen SR (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate (No. 939). US Department of Agriculture.

Overbeck J, Anagnostidis K, Economou-Amilli A (1982). A limnological survey of three Greek lakes: Trichonis, Lyssimachia and Amvrakia. Archiv für Hydrobiologie 95:365-394.

Panitsa M, Tzanoudakis D, Sfenthourakis S (2008). Turnover of plants on small islets of the eastern Aegean Sea within two decades. Journal of Biogeography 35(6):1049-1061. *https://doi.org/10.1111/j.1365-2699.2007.01846.x*

Papastergiadou E (1990). Phytosociological and ecological studies of aquatic macrophytes (hydrophytes). Northern Greece. PhD Thesis, Aristotelian University of Thessaloniki.

Papastergiadou ES, Retalis A, Kalliris P, Georgiadis T (2007). Land use changes and associated environmental impacts on the Mediterranean shallow Lake Stymfalia, Greece. In: Shallow Lakes in a changing world. Springer, Dordrecht, pp 361-372.

Pavlidis G (1985). Geobotanical Study of the Prespa National Park. University of Thessaloniki, Thessaloniki.

Perzanowska J, Korzeniak J, Chmura D (2019). Alien species as a potential threat for Natura 2000 habitats: a national survey. PeerJ 7:e8032.

Pyšek P, Chocholousková Z, Pyšek A, Jarošík V, Chytrý M, Tichý L (2004). Trends in species diversity and composition of urban vegetation over three decades. Journal of Vegetation Science 15(6):781-788. *https://doi.org/10.1111/j.1654-1103.2004.tb02321.x*

Quantum GIS Development Team (2020). QGIS Geographic Information System. Open-Source Geospatial Foundation Project. Retrieved 2021 July 2 from *http://qgis.osgeo.org*

Rhoades JD (1982). Soluble salts. In: Page AL (Ed). Methods of soil analysis. Part II. Madison: American Society of Agronomy Monograph No. 9, pp 167-179.

Rodeghiero M, Rubio A, Díaz Pinés E, Romanyà J, Marañón Jiménez S, Levy GJ, … Sirca C (2011). Soil carbon in Mediterranean ecosystems and related management problems. Soil carbon in sensitive European ecosystems: from science to land management 175-218.

Raunkiaer C (1934). The life forms of plants and statistical plant geography. Being the collected papers of C. Raunkiaer. Oxford University Press, London.

Sarika-Hatzinikolaou M (1999). Floristic and phytosociological study on aquatic ecosystems of Epirus (NW Greece). PhD thesis, University of Athens. [in Greek]

Schuster B, Diekmann M (2003). Changes in species density along the soil pH gradient—evidence from German plant communities. Folia Geobotanica 38(4):367-379. *https://doi.org/10.1007/BF02803245*

Smith RL (1980). Ecology and field biology. Harper and Row Publishers, New York.

Soil Science Division Staff (2017). Soil Survey Manual. Ditzler C, Scheffe K, Monger HC (Eds). USDA Handbook 18. Government Printing Office, Washington, D.C.

Soons MB, Hefting MM, Dorland E, Lamers LP, Versteeg C, Bobbink R (2017). Nitrogen effects on plant species richness in herbaceous communities are more widespread and stronger than those of phosphorus. Biological Conservation 212:390-397. *https://doi.org/10.1016/j.biocon.2016.12.006*

Stevens CJ, Dise NB, Mountford JO, Gowing DJ (2004). Impact of nitrogen deposition on the species richness of grasslands. Science 303(5665):1876-1879. *https://doi.org/10.1126/science.1094678*

Ter Braak CJ (1987). The analysis of vegetation-environment relationships by canonical correspondence analysis. Vegetatio 69(1):69-77.

Ter Braak CT, Smilauer P (1998). CANOCO reference manual and user's guide to Canoco for Windows: Software for Canonical Community Ordination (version 4). Microcomputer Power, Ithaca, New York.

Thomatou A-A, Triantafyllidou M, Chalkia E, Kehayias G, Konstantinou I, Zacharias I (2013). Land use changes do not rapidly change the trophic state of a deep lake. Amvrakia Lake, Greece. Journal of Environmental Protection 4(5):426-434. *https://doi.org/10.4236/jep.2013.45051*

Triantafyllidis V, Zotos A, Kosma C, Kokkotos E (2020). Effect of land-use types on edaphic properties and plant species diversity in Mediterranean agroecosystem. Saudi Journal of Biological Sciences 27(12):3676-3690. *https://doi.org/10.1016/j.sjbs.2020.08.012*

Tutin TG, Burges NA, Chater AO, Edmondson JR, Heywood VH, Moore DM, ... Webb DA (1968-80, 1993). Flora Europaea 1-5. Cambridge University Press, Cambridge, UK.

Zacharias I, Bertachas I, Skoulikidis N, Koussouris T (2002). Greek lakes: Limnological overview. Lakes & Reservoirs: Research & Management 7(1):55-62. *https://doi.org/10.1046/j.1440-1770.2002.00171.x*

Zelnik I (2012). The presence of invasive alien plant species in different habitats: case study from Slovenia. Acta Biologica Slovenica 55(2):25-38.

Zelnik I, Čarni A (2013). Plant species diversity and composition of wet grasslands in relation to environmental factors. Biodiversity and Conservation 22(10):2179-2192. *https://doi.org/10.1007/s10531-013-0448-x*

Zervas D, Tsiaoussi V, Kallimanis AS, Dimopoulos P, Tsiripidis I (2019). Exploring the relationships between aquatic macrophyte functional traits and anthropogenic pressures in freshwater lakes. Acta Oecologica 99:103443.

Zorrilla-Miras P, Palomo I, Gómez-Baggethun E, Martín-López B, Lomas PL, Montes C (2014). Effects of land-use change on wetland ecosystem services: A case study in the Doñana marshes (SW Spain). Landscape and Urban Planning 122:160-174. *https://doi.org/10.1016/j.landurbplan.2013.09.013*

Zotos A (2006). Flora, vegetation ecology and management proposals for the wet meadows and reed thickets of the lakes Trichonida and Lysimachia (W. Greece). PhD Thesis, University of Ioannina. [in Greek]