# ABUNDANCE, DIVERSITY AND DISTRIBUTION OF MACROPHYTE COMMUNITIES IN NEIGHBORING LAKES OF DIFFERENT TROPHIC STATES AND MORPHOLOGY IN NORTH-CENTRAL GREECE

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*Abstract* - The role of aquatic vegetation in wetland ecosystems is closely related with their abundance, diversity and distribution, which in turn represents synergy of various environmental factors. The floristic composition of the aquatic vegetation in two neighboring lakes (Vegoritida and Petron) in north-central Greece was investigated by means of 160 relevés, which were recorded using the Braun-Blanquet method. The analysis of relevés based on TWINSPAN clustering showed the existence of 10 plant communities from the *Lemnetea, Potametea, Phragmito-Magnocaricetea* and *Juncetea maritimi* classes. The most important environmental factors for the vegetation differentiation in the study area, according to the ordination diagram, are light intensity and water depth of the habitats. The plant species diversity was quantified with species richness, Shannon Diversity and evenness indices at a scale of each relevé, with a sampling size of 20 m$^2$. There was a clear differentiation between the relevés at the more eutrophic Petron Lake and those at Vegoritida Lake. The mean plot diversity was also calculated for each plant community, to enable comparison of the diversity indices among the communities at the plot level.

*Key words:* aquatic vegetation, lakes, classification, plant communities, diversity indices, environmental factors.

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## INTRODUCTION

Wetlands are among the Earth's most productive ecosystems. In the Mediterranean region, wetlands are characterized by biological richness and play an important role in providing a range of ecosystem functions and services, such as stabilizing water supplies, cleaning polluted waters, protecting shorelines, supporting biodiversity and habitat for flora and fauna species (Mitsch and Gosselink, 1993; Williams, 1990). Britton and Crivelli (1993) estimated the area covered by wetlands in the Mediterranean basin to be 21,000 km$^2$, of which 4,700 km$^2$ are coastal lagoons, 2,800 km$^2$ are freshwater lakes and marshes and 11,600 km$^2$ are temporary salt lakes. In many countries, wetlands are under increasing pressure from anthropogenic activities, including conversion for intensive agricultural use and other industrial and residential uses. According to Green et al. (2002), a significant proportion of wetlands have been lost in Mediterranean countries in the last century, with the total wetland loss in Greece comprising 61%.

Greece, a typical Mediterranean country in south-eastern Europe, is characterized by a multitude of small basins with small lakes. The geographical and altitudinal distribution of the Greek lakes shows that most of them are situated in the western and northwestern parts of the country (Zacharias et al., 2002), on the karstic calcareous zone running from the Alps to southern Greece and through former Yugoslavia (Boegli, 1978). Geomorphologically, recent natural lakes belong to discrete old basins and lake groups and are the relicts of greater lake systems that occupied the country from the Tertiary and Quaternary (Leontaris, 1967; Psilovikos, 1977; Pavlides and Mountrakis, 1987; Mercier et al., 1989). There are about 40 natural lakes on Greek territory, covering an area of approximately 560 km², which is less than 0.5% of the country's total area (Skoulikidis et al., 1998).

In spite of their international importance, wetlands in Greece are constantly under threat. Greece is a European Union (EU) member state and a Ramsar convention partner, and, as a result, is obliged to protect, sustainably manage, and conserve its remaining wetlands. Rapid economic development over the past few decades has led not only to a remarkable increase in water demand, disturbances in the hydrological balance in catchment areas, but also wide-spread pollution practices, and degradation of the quality of water resources.

Aquatic plants and their communities are an important component of the littoral zone in various types of lakes. They form characteristic spatial patterns (Hutchinson, 1975; Spence, 1982; Klosowski, 1992), which often constitute a transitional boundary between the open water and reed swamp communities. Macrophytes are involved in several feedback mechanisms that tend to keep the water clear even in relatively high nutrient loadings (Moss, 1990). In addition, macrophytes have been reported to notably affect the lake nutrient status, resuspension of bottom material and water turbidity (James and Barko, 1990; Sand-Jensen and Borum, 1991; Horppila and Nurminen, 2001). Aquatic plants and their communities may furthermore be good indicators of the changes occurring in lakes because of human-induced acidification and eutrophication (Roelofs, 1983; Lehmann and Lachavanne, 1999). Moreover, macrophytes provide shelter for invertebrates and small fishes, and form spawning "substrates" for many coarse fishes.

In this paper, the macrophyte flora and vegetation distribution of a wetland complex which consists of two entirely different lakes (morphologically and trophic state levels), are investigated. More precisely, the objectives of this study are (i) to identify the different plant communities present in the aquatic ecosystems, (ii) to investigate the environmental factors that influence their abundance and distribution, and (iii) to quantify the plant species diversity using indices based on plant species composition of the communities.

## MATERIALS AND METHODS

### *Study area*

The study area is located in north-central Greece and is confined by the coordinates of 40° 49′ to 40° 39′ N and 21° 40′ to 21° 50′ E (Fig. 1). The two lakes (Vegoritida and Petron) and the surrounding hills have been included in the European network of protected areas NATURA 2000 (Dafis et al., 1996). The importance of the area is derived from the presence of different habitat types and numerous species of flora and fauna.

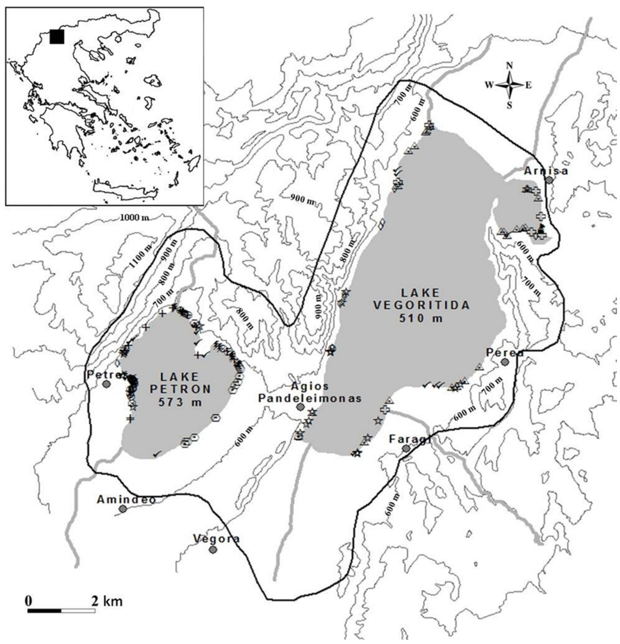


**Fig. 1.** Geographical position and detail map of the study area. The different symbols show the location of the relevés in the study area. Group numbers correspond to the vegetation units in table 3.
◊ : group 1, 6 : group 2, 0: group 3, ,: group 4,
d: group 5, 2: group 6, + : group 7, ⊗ : group 8,
i: group 9, -: group 10.

Vegoritida is a deep and large lake, referred as meso-eutrophic (Skoulikidis et al., 2008), with an elongated shape in a north-south direction. According to Paraschoudis et al. (2001), in 1956, it had a volume of 2500 x $10^6$ $m^3$ and a surface area of about 60 $km^2$. Today, due to intense water drainage for hydroelectric power production, the water volume of the lake has decreased to 500 x $10^6$ $m^3$, resulting in the reduction of the lake area to 30 $km^2$. The water level of the lake has decreased from approximately 542 m a.s.l. in 1956 to 510 m a.s.l. today.

Petron Lake is situated close to Vegoritida and is a small, shallow and eutrophic lake (Skoulikidis et al., 1998). It has a maximum depth of 3 m and a surface area of about 8 $km^2$. The water level of the lake is 573 m a.s.l.

Both lakes are part of a greater water complex that includes another two lakes, Cheimaditida and Zazari. This whole ecosystem, once composing the deeper remaining parts of the older and large Eordea Basin, is a well-known and very important wetland complex that sustains a large variety of fishes, birds, and plant species. The Zazari, Cheimaditida and Petron Lakes are interconnected through ditches and are discharged into Vegoritida Lake through an artificial tunnel.

Geologically, aquatic communities develop mainly on recent alluvial deposits around the lakes. The climate of the area is submediterranean-continental, characterized by harsh winters and mild drought in summers (Walter and Lieth, 1964), with a mean annual precipitation of 437 mm (1964-2008). In relation to the Mediterranean bioclimatic divisions, the area belongs to the sub-humid zone with harsh winters (Emberger, 1955; Mavromatis, 1980).

*Data analysis*

According to the Braun-Blanquet method (Braun-Blanquet, 1964), a total of 160 phytosociological relevés were sampled during the summer of 2005. The sample plot size was (5)10-40(-60) $m^2$, depending on the homogeneity of the vegetation. Species

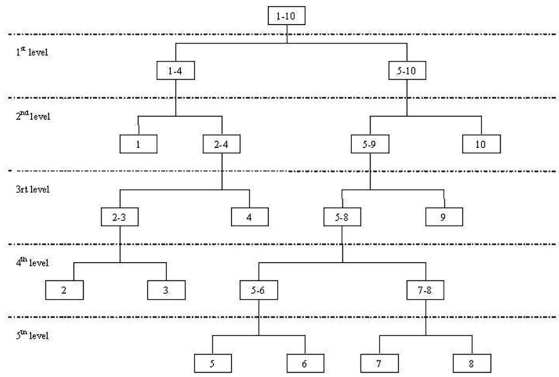


**Fig. 2.** Dendrogram with clusters obtained by the two-way indicator species analysis (TWINSPAN). Numbers correspond to the vegetation units in table 3.

cover abundance was recorded using the 7-grade scale of Braun-Blanquet. For each relevé, the water depth and the distance from the shoreline were measured. Additionally, the coordinates of the relevés were recorded with the help of a GPS device. Samples of the vascular plant taxa have been deposited in the Herbarium of the Institute of Systematic Botany and Phytogeography of the Aristotle University of Thessaloniki (TAU).

The relevés were entered in TURBOVEG version 2.32a (Hennekens and Schaminée, 2001). They were then imported into the JUICE version 6.3 (Tichý, 2002). Taxa occurring in one relevé were omitted before the analyses in order to reduce noise. Vegetation data were classified using the two-way indicator species analysis (Hill, 1979a), a commonly used program in ecological studies for the classification of vegetation communities according to their floristic similarity (Kent and Coker, 1992). Four pseudospecies cut levels were selected (0, 5, 25, and 50), and five levels of divisions were applied. TWINSPAN was applied using JUICE version 6.3 (Tichý, 2002).

Differential taxa for the distinguished plant communities were determined using the algorithm proposed by Tsiripidis et al. (2009). Furthermore, in order to quantify the fidelity values of the taxa, the phi-coefficient was calculated between the groups

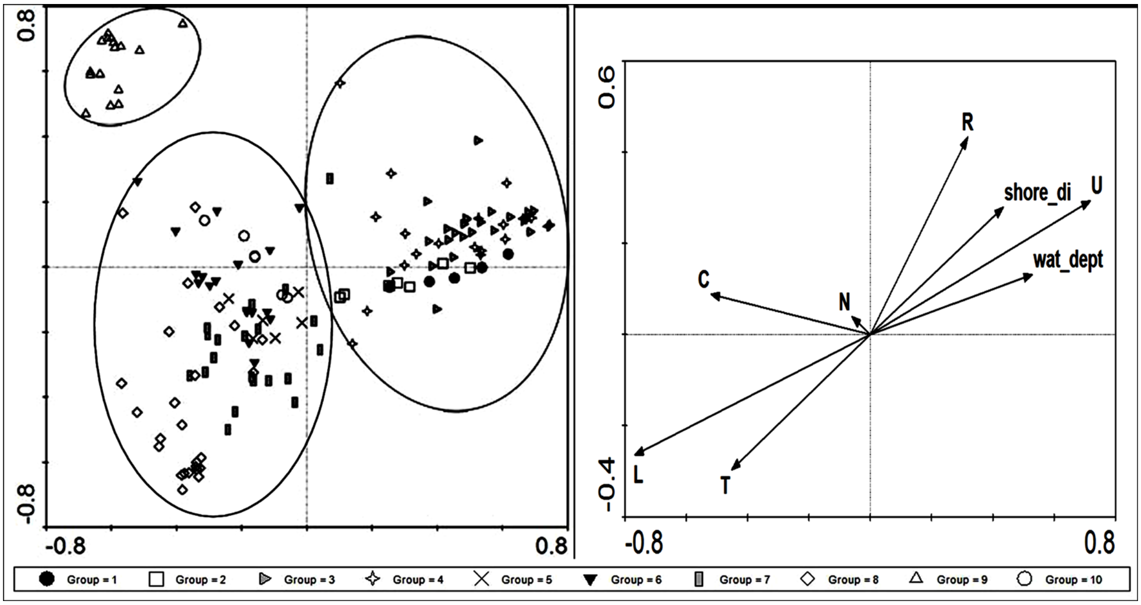


**Fig. 3.** PCA diagrams of all relevés and explanatory variables along the first two ordination axes.
**Abbreviations:** L - light, T - temperature, M - moisture, R - reaction, N - nitrogen, wat_dept - water depth, shore_di - shore distance, C - continentality, S - salinity.

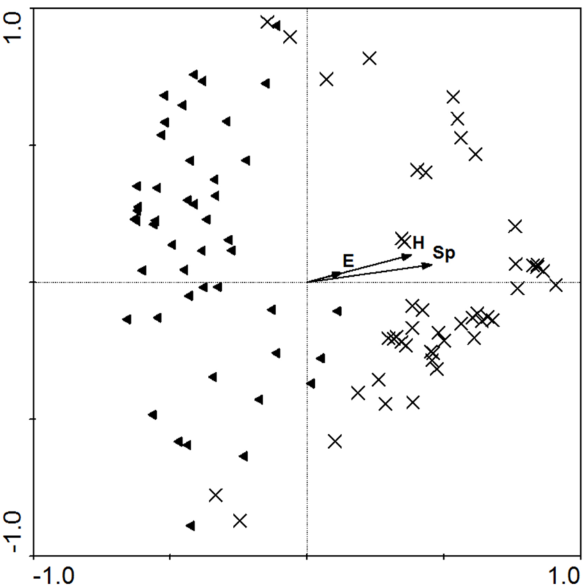


**Fig. 4.** PCA diagrams of 103 relevés with plot size 20 m$^2$ and three diversity indices as explanatory variables along the first two ordination axes.
**Abbreviations:** S - Species Richness, H - Shannon Diversity Index and E - Evenness.
**Symbols**: - relevés conducted at Lake Petron and
- relevés conducted at Lake Vegoritida

differentiated positively and those differentiated negatively, positive-negatively, or not-differentiated at all. The value 0.45 was chosen as the fidelity threshold to accept a taxon as differential for a group or a combination of groups.

Principal Component Analysis (PCA), an indirect gradient analysis technique (Hill, 1979b; ter Braak, 1986), was chosen as an ordination method and was applied with CANOCO version 4.5 (ter Braak and Šmilauer, 2002). Before the PCA analysis, cover abundances of the taxa were transformed according to Legendre and Gallagher (2001), in order to avoid giving smallest weights to monospecific relevés. The PCA diagrams were used for both the correction and the interpretation of the TWINSPAN classification. In order to facilitate ordination diagram interpretation, passive explanatory variables were used in PCA. These variables concern water depth, distance from the shoreline, and the Ellenberg indicator values for the relevés. Ellenberg indicator values concern light, temperature, continentality, moisture, reaction, and nitrogen. The indicator values (IV) of taxa were taken from the list covering Italy (Pignatti et al.,

**Table 1.** Partitioning of the correlations (Kendall's coefficient) between PCA relevé scores and the explanatory variables. *, ** = Significance level at the 0.05 and 0.01, respectively.

| Axis | 1 | 2 |
|---|---|---|
| L | -0.455** | -0.243** |
| T | -0.217** | -0.252** |
| C | -0.339** | 0.103 |
| M | 0.505** | 0.268** |
| R | 0.190** | 0.267** |
| N | -0.018 | -0.033 |
| wat_dept | 0.441** | 0.202** |
| shore_di | 0.397** | 0.308** |

2005), as well as from the extended list distributed by Pignatti during the 16th Workshop of the European Vegetation Survey in 2006. Correlations between the PCA relevé scores and the explanatory variables were calculated using the non-parametric Kendall coefficient.

The plant species diversity was quantified using indices based on the plant species composition of the communities in relevés with the same size (20 $m^2$). From among the indices applicable for estimating the diversity, three widely used were chosen for the study area due to the simplicity in their computation, and in order to compare the results with existing literature. The three indices, Species number (also known as species richness), Shannon diversity and evenness were calculated at a scale of each sampling plot.

The species number (S) is the number of species found in an area of specific size.

The Shannon diversity index (H) takes into account the relative abundance of the plant species, whereas the evenness (E) is the quotient of the Shannon index to the maximum value that the Shannon diversity index can have, with the same species number and equal species abundance.

The plant species richness, Shannon diversity index and evenness were calculated for the 103 relevés with a plot size of 20 $m^2$, and PCA analysis was carried out with the explanatory variables being the three diversity indices.

A mean plot diversity was also calculated for each plant community (average of the plot diversity of its relevés), to enable a comparison of the diversity indices among the communities at the plot level.

The nomenclature of plant communities was checked for validity according to ICPN (Weber et al., 2000). The characterization of differential species for higher-rank syntaxa followed Mucina (1997).

## RESULTS

The results of the TWINSPAN analysis are summarized in the dendrogram on Fig. 2. The phytosociological relevés were classified into ten groups, which correspond to ecologically interpretable vegetation communities (Table 3). Groups 1 - 4 included all the relevés with submerged *Magnopotamion* and *Parvopotamion* communities and were clearly differentiated from all other groups. This type of vegetation forms a zone adjacent to the open water, in addition to occurring on steep littoral slopes that are devoid of reed swamp vegetation, such as the northwest side of the Vegoritida Lake. Each group was characterized by the dominance of one or two species; they formed dense stands and were poor in species composition. Group 1 was characterized by a strong dominance of *Myriophyllum spicatum*, while all relevés (except one) were at Vegoritida Lake. Group 2 occured in areas with relatively low water depth than the remaining, and was differentiated from others by the dominance of *Najas marina*. All the relevés of the second and third groups were collected from the littoral zone in the Vegoritida Lake. Group 3 consisted of relevés that formed continuous belts of mainly submerged species, with the dominance of *Vallisneria spiralis*

**Table 2.** Average values of the diversity indices at the plot level for the five communities, for which at least 10 relevés with sampling plot size 20 $m^2$ were available.
**Abbreviations:** S - Species Richness, H - Shannon Diversity Index, E - Evenness, Myr_spi - Myriophylletum spicati, Pot_Vall - Potamo-Vallisnerietum, Pot_pect - Potametum pectinati, Ch.v_Utric - Chara vulgaris - Utricularia vulgaris comm. and Eleoch - Eleocharitetum uniglumis.

| Plant community | Number of relevés | S | H | E |
|---|---|---|---|---|
| Eleoch | 10 | **7** | **0.67** | 47.8 |
| Ch.v_Utric | 10 | 5 | 0.38 | **57** |
| Pot_Vall | 10 | 4 | 0.38 | 46.8 |
| Pot_pect | 10 | 4 | 0.27 | 54.2 |
| Myr_spi | 10 | 1 | 0.08 | 33.9 |

and *Potamogeton perfoliatus*. The relevés of Group 4 occured in both the lakes and were differentiated by the dominance of *Potamogeton pectinatus*. Group 5 included relevés from the Petron Lake, with the dominance of the helophyte *Schoenoplectus litoralis* and pleustophyte *Lemna trisulca*. This community grew in biotopes with a fluctuating water regime and formed stands towards the line of the bank. Groups 6 and 7 consisted of relevés sampled at Petron Lake (except two that were collected at the southeastern side of Vegoritida Lake). They formed dense beds, with the dominance of *Bolboschoenus maritimus* and *Chara hispida* var. *hispida* in the relevés of the sixth group and *Chara vulgaris* var. *vulgaris* and *Utricularia vulgaris* in the relevés of seventh group. Groups 8 and 9 represented vegetation growing in the transition zone between land and water. Small helophytes (*Alisma* sp., *Eleocharis* sp., and *Juncus* sp.) grew at a depth of 0 - 0.3 m, whereas tall helophytes (*Phragmites australis*, *Schoenoplectus lacustris*, and *Typha angustifolia*) grew in the deeper areas (0 – 1 m) and formed stands or belts of different widths in nearly all the areas of Petron Lake and in the southern and northeastern sides of Vegoritida Lake. The dominant species in the relevés of the eighth group was *Eleocharis uniglumis*, whereas those of the ninth group predominantly consisted of *Phragmites australis*. The tenth group consisted of relevés at the Vegoritida Lake. These relevés formed stands characterized by the dominance of the bryophyte, *Ricciocarpus natans*.

PCA analysis was used as an ordination method to identify the underlying environmental gradients that influenced vegetation distribution in the study area. The first PCA diagram of all relevés (Fig. 3) showed two clusters (cluster of the groups 1-4 and cluster of the groups 5-8 and 10). The relevés of Group 9 appeared as outliers, occurring at the upper left part of the diagram and corresponded to ass. *Phragmitetum communis*. There was only a slight overlap between the two clusters along the second axis. The relevés of the submerged *Potametea* communities clustered in the right part of the diagram, except for the relevés of Group 7, which clustered together with the emerged and floating vegetation and occurred at the left part of the PCA diagram. The first axis (eigenvalue 0.176) was significantly correlated with moisture, light and water depth (Table 1), and represented an ecological gradient expressing the emerged, floating, or submerged vegetation type. Axis 2 (eigenvalue 0.109) was correlated with many variables and it is quite unclear which gradient it represents.

The second PCA diagram of the 103 relevés with the variables being the three diversity indices, showed clusters of the relevés at Lake Petron, at the right part of the diagram (Fig. 4).

The average values of the diversity indices for the five communities, for which at least 10 relevés with sampling plot size 20 $m^2$ were available, are given in Table 2. The species richness and Shannon diversity

**Table 3.** Synoptic constancy table of plant communities: 1 - Myriophylletum spicati, 2 - Najadetum marinae, 3 - Potamo-Vallisnerietum, 4 - Potametum pectinati, 5 - Schoenoplectus litoralis - Lemna trisulca comm., 6 - *Bolboschoenus maritimus* - Chara hispida comm., 7 - Chara vulgaris - Utricularia vulgaris comm., 8 - Eleocharitetum uniglumis, 9 - Phragmitetum communis and 10 - Ricciocarpetum natantis. Taxa occurring in one relevé were omitted.

| Number of cluster (plant commu | Total absolute | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of relevés | | 11 | 7 | 24 | 21 | 7 | 19 | 21 | 25 | 19 | 6 |
| Average species number | | 1.36 | 3.28 | 3.91 | 3.52 | 6.14 | 7.78 | 4.85 | 6.26 | 4.42 | 5.5 |
| **Differential taxa for a group or a combination of groups** | | | | | | | | | | | |
| Myriophyllum spicatum | 59 | **100** | **78** | **75** | **62** | **57** | 6 | 14 | 8 | 5 | . |
| Najas marina | 15 | . | **89** | 21 | 10 | . | . | . | . | . | . |
| Potamogeton pusillus | 4 | . | **33** | 4 | . | . | . | . | . | . | . |
| Potamogeton perfoliatus | 42 | 9 | **44** | **100** | **62** | . | . | 5 | . | . | . |
| Potamogeton pectinatus | 49 | 18 | 22 | **33** | **100** | . | 12 | **33** | 19 | 11 | . |
| Vallisneria spiralis | 31 | . | **33** | **83** | **38** | . | . | . | . | . | . |
| Schoenoplectus litoralis | 17 | . | . | . | . | **100** | 6 | 14 | 15 | 11 | . |
| Lemna trisulca | 9 | . | . | . | . | **86** | 6 | 5 | 4 | . | . |
| Bolboschoenus maritimus | 22 | . | . | 4 | . | . | **71** | 5 | 8 | **32** | . |
| Chara hispida var. hispida | 13 | . | . | 4 | 5 | . | **59** | 5 | . | . | . |
| Typha angustifolia | 24 | . | . | . | . | **71** | **47** | 14 | 15 | 16 | 17 |
| Rumex palustris | 19 | . | . | . | . | **29** | **53** | 5 | 4 | 5 | **83** |
| Oenanthe aquatica | 11 | . | . | . | . | **29** | **53** | . | . | . | . |
| Alisma gramineum | 28 | . | **44** | **38** | 14 | . | **59** | 10 | 4 | . | . |
| Butomus umbellatus | 9 | . | . | . | . | 14 | **41** | . | . | 5 | . |
| Alisma plantago-aquatica | 11 | . | 11 | . | . | . | **41** | 5 | 4 | 5 | . |
| Veronica anagalloides | 11 | . | . | . | . | . | **41** | 10 | 4 | 5 | . |
| Chara vulgaris var. vulgaris | 25 | . | . | . | 5 | . | 6 | **81** | 15 | 11 | . |
| Utricularia vulgaris | 24 | . | . | . | 5 | 29 | 18 | **71** | 8 | 5 | . |
| Eleocharis uniglumis | 38 | . | . | . | . | **57** | 6 | **33** | **92** | 11 | . |
| Mentha aquatica | 31 | . | . | . | 5 | . | 6 | 10 | **73** | **37** | 17 |
| Juncus articulatus | 12 | . | . | . | . | . | 6 | 10 | **38** | . | . |
| Juncus gerardi | 17 | . | . | . | . | . | 6 | 14 | **46** | 5 | . |
| Phragmites australis | 68 | . | . | 17 | 24 | **43** | **59** | **52** | **50** | **100** | **67** |
| Schoenoplectus lacustris | 38 | . | . | . | . | **57** | **41** | **24** | **50** | **47** | . |
| Ricciocarpos natans | 6 | . | . | . | . | . | . | . | . | . | **100** |
| Lemna minor | 8 | 9 | . | . | 10 | . | . | . | . | . | **83** |
| Lolium temulentum | 5 | . | . | . | . | . | . | . | . | . | **83** |
| Bromus scoparius | 3 | . | . | . | . | . | . | . | . | . | **50** |
| **Cl. Phragmito-Magnocaricetea** | | | | | | | | | | | |
| Lycopus europaeus | 9 | . | . | . | . | . | 6 | . | 27 | 5 | . |
| Phalaris arundinacea | 5 | . | . | . | . | . | 12 | . | 4 | 11 | . |
| Eleocharis palustris | 3 | . | . | . | . | . | 6 | . | . | 11 | . |
| Sparganium erectum | 2 | . | . | . | . | . | 6 | . | . | 5 | . |
| **Cl. Potametea** | | | | | | | | | | | |
| Ranunculus trichophyllus | 4 | . | . | . | . | . | 12 | . | 4 | 5 | . |
| Persicaria hydropiper | 2 | . | . | . | . | . | . | . | . | 11 | . |
| **Cl. Lemnetea** | | | | | | | | | | | |
| Azolla filiculoides | 2 | . | . | . | 10 | . | . | . | . | . | . |
| **Other species** | | | | | | | | | | | |
| Agrostis stolonifera | 36 | . | . | 4 | 5 | 29 | 29 | 29 | 69 | 16 | . |
| Drepanocladus aduncus | 8 | . | 11 | . | . | 14 | 29 | 5 | . | . | . |
| Teucrium scordium ssp. scordic | 7 | . | . | . | . | . | . | . | 12 | 21 | . |
| Potentilla reptans | 6 | . | . | . | . | . | . | . | 8 | 21 | . |
| Epilobium hirsutum | 6 | . | . | . | . | . | 12 | 14 | . | 5 | . |
| Rorippa sylvestris | 5 | . | . | . | . | . | 6 | 14 | . | 5 | . |
| Scirpus holoschoenus | 4 | . | . | . | . | . | . | . | 19 | . | . |
| Persicaria amphibia | 4 | . | . | . | . | . | . | . | 15 | . | . |
| Cladophora glomerata | 3 | . | . | . | . | . | . | . | 4 | 11 | . |
| Stachys palustris | 3 | . | . | . | . | . | 12 | . | . | 5 | . |
| Lythrum salicaria | 3 | . | . | . | . | . | . | . | 4 | 11 | . |
| Solanum nigrum | 2 | . | . | . | . | . | . | . | . | 11 | . |
| Paspalum paspalodes | 2 | . | . | . | . | . | . | 5 | . | . | 17 |
| Echinochloa crus-galli | 2 | . | . | . | . | . | . | . | . | 5 | 17 |
| Polypogon monspeliensis | 2 | . | . | . | . | . | 12 | . | . | . | . |
| Juncus effusus | 2 | . | . | . | . | . | 6 | . | 4 | . | . |
| Verbena officinalis | 2 | . | . | . | . | . | . | . | . | 5 | 17 |

index followed a similar pattern, with ass. *Eleocharitetum uniglumis, Potamo-Vallisnerietum* and *Chara vulgaris-Utricularia vulgaris* comm. being the three most diverse communities. The third diversity index (evenness) showed a different pattern, with the *Chara vulgaris-Utricularia vulgaris* comm. showing the highest diversity value, followed by the associations *Potametum pectinati* and *Eleocharitetum uniglumis*.

The first axis was negatively correlated with all the diversity indices and represented a gradient that expressed higher diversity in the sampling plots of Lake Petron than those of Lake Vegoritida.

## DISCUSSION

The PCA diagram of the whole data set reveals that the most important environmental factors for the vegetation differentiation are moisture, light and water depth of the habitats. The attenuation of light causes the disappearance of submerged macrophytes from deeper parts of the lake, which become abundant in the shallow parts and cause intense interspecific competition (Schmieder, 1996). According to Hrivnák (2009), species richness increases with decreasing water depth and that is caused by the presence of true aquatic plants as well as marsh and wet meadow species in shallower waters, representing appropriate conditions for all species groups. This is possibly a reason for the positioning of the relevés of Group 7 in the left part of the first PCA diagram. The species composition of this community includes both submerged, emerged and charophyte species, creating a mosaic appearance of the vegetation.

Moreover, plant communities are dynamic entities undergoing temporal and spatial changes in floristic composition caused by site conditions and competition between plants. The trophic state of a lake and the physico-chemical parameters associated with it (morphology of the lake basin, throughflow, flushing rate and water quality characteristics) exert a significant impact on the occurrence of different types of macrophyte vegetation (Coops et al., 1999; Vestergaard and Sand-Jensen, 2000; Piotrowicz et al., 2006; Joniak et al., 2007).

Five of the ten communities that were recorded in the study area, were common to both lakes, with differences in the extent of the distribution areas. This differentiation was probably related to the lakes' size, morphology and eutrophication of the water. According to other aquatic studies in north Greece (Papastergiadou and Babalonas, 1993a, 1993b; Conides et al., 1995; Zacharias et al., 2002; Stefanidis and Papastergiadou 2010), physico-chemical parameters of the water of the studied lakes have changed in the last decades as a result of nutrient enrichment from anthropogenic impacts.

*Najadetum marinae, Potamo-Vallisnerietum* and *Ricciocarpetum natantis* were found only in Vegoritida Lake. The relevés of the former association were recorded near Arnisa village and possibly became temporarily invasive after the destruction of reed stands correlated with the succession processes of the vegetation. Alternatively, the location could have reflected the anthropogenic influence of cultivation and grazing.

*Schoenoplectus litoralis-Lemna trisulca* comm. and *Chara vulgaris-Utricularia vulgaris* comm. were recorded only in Petron Lake. The first community seems to confirm human activities in the study area, with the presence of submerged and marsh plant species toward the line of the bank, creating a mosaic appearance of aquatic vegetation. The second vegetation type indicates stagnant, shallow waters and may be the first successional stage leading to a stable macrophyte-dominant ecosystem. Moreover, charophytes are supposed to be superior competitors for space and nutrients in comparison to angiosperms and are generally recognized as one of the first colonizers in shallow water bodies (Wade, 1990; Lambert-Servien et al., 2006; Van Nes et al., 2002c).

The second PCA diagram shows the highest diversity indices in the relevés of Petron Lake, confirming the eutrophic character of the lake. In Greece, shallow lakes are eutrophic, whereas deep ones can be classified as oligo-mesotrophic (Skoulikidis et al., 1998). Our results agree with those of Schulthorpe (1967) who considers that eutrophic lakes support significantly more species number. Moreover, there is a relation between a trophic state and increased zooplankton abundance in lakes (Jeppesen et al., 1997; Blindow et al., 2000; Kagalou et al., 2003b), and according to Stefanidis and Papastergiadou (2010), Lake Vegoritida was characterized by lower total zooplankton density than Petron Lake, confirming the less eutrophic character of Vegoritida.

A total of 49 hydrophytic taxa belonging to 28 families and 35 genera were recorded in the study area (Pirini et al., 2010). The taxa recorded in Petron Lake (42 hydrophytes), exceeded those present in Vegoritida Lake (30 hydrophytes) which is deeper and four times larger. In contrast to our results, Toivonen and Huttunen (1995) consider that a large lake provides a wider array of habitats than a smaller one, and therefore a more polymorphic macrophyte flora could be expected. The different morphology of the basin of the Vegoritida Lake, which is deep and not favorable for emergent plants over a large proportion of its shoreline, is a reason for the lower diversity indices were observed in the relevés of this lake.

Each diversity index demonstrates a specific aspect of the diversity of a plant community. The examined species richness is the simplest form of diversity index, and shows high diversity in communities with higher species number. High species diversity indicates a high complexity of organization, which is often associated with high stability, although this may not always be the case. In some cases there are species-poor, but ecologically stable ecosystems such as moors, heathlands, etc. (Bastian and Schreiber, 1994). Shannon, the second examined diversity index, is a measure of the probability of finding a species in a community (Plachter, 1991). In aquatic vegetation monodominant stands or belts were observed relatively frequently (Topić, 1989; Balevičienė and Balevičius, 2006; Papastergiadou et al., 2007; Imeri et al. 2008), and this is a reason the same pattern was observed for the species richness and Shannon diversity index in the study area. Relevés dominated by one or two species present low diversity, in comparison to those characterized by the coexistence of many species, hence the community Myriophylletum spicati showed the least diversity indices. The evenness diversity index provides information about species distribution and indicates whether the high diversity of a plant community is due to the presence of many species with different abundances or to a smaller number of species with a more homogeneous distribution, and therefore shows different pattern, with *Chara vulgaris-Utricularia vulgaris* comm. presented the highest value of evenness diversity index.

However, high diversity can be the result of human influence, as is the case with some managed forest types (Reif et al., 2001). For this reason the absolute species number does not mean much for the quality of an ecosystem and it should be seen in relation to the specific development stage, the intensity of the human influence, the site conditions, and so on.

In general, the occurrence of macrophyte vegetation improves the quality of water entering a lake. The main threat to aquatic ecosystems arises from the cultivation of surrounding land in addition to the lack of knowledge regarding the importance of wetland ecosystems among the local population. Detailed knowledge concerning the floristic composition, ecology and environmental factors that influence vegetation types, provide a strong basis to research and helps in the improvement of conservation and management practices in relation to the vegetation and biodiversity of wetland ecosystems.

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