A phytosociological survey of aquatic vegetation in the main freshwater lakes of Greece

Dimitrios Zervas¹², Ioannis Tsiripidis¹, Erwin Bergmeier³, Vasiliki Tsiaoussi²

¹ Department of Botany School of Biology, Aristotle University of Thessaloniki, Greece
² Greek Biotope/Wetland Centre (EKBY), The Goulandris Natural History Museum, Thessaloniki, Greece
³ Department of Vegetation and Phytodiversity Analysis, University of Göttingen, Germany

Corresponding author: Dimitrios Zervas (dzervas@ekby.gr)

Abstract

Aims: This study aims to contribute to the knowledge of European freshwater lake ecosystems with updated and new information on aquatic plant communities, by conducting national-scale phytosociological research of freshwater lake vegetation in Greece. Moreover, it investigates the relationship between aquatic plant communities and lake environmental parameters, including eutrophication levels and hydro-morphological conditions. Study area: Lakes in Greece, SE Europe. Methods: 5,690 phytosociological relevés of aquatic vegetation were sampled in 18 freshwater lake ecosystems during 2013–2016. The relevés were subjected to hierarchical cluster and indicator species analyses in order to identify associations and communities of aquatic vegetation, as well as to describe their syntaxonomy. Multiple regression analysis was applied to investigate the relationship between vegetation syntaxa and environmental parameters of lakes, i.e. physico-chemical parameters and water level fluctuation. Results: Ninety-nine plant taxa belonging to 30 different families were recorded. Forty-six vegetation types were identified and described by their ecological characteristics, diagnostic taxa and syntaxonomical status. Thirteen vegetation types, the largest number belonging to the vegetation class Charoreta, are considered to be new records for Greece. The distribution of the vegetation types recorded in the 18 freshwater lakes was found to depend on environmental parameters and levels of eutrophication. Conclusions: An updated aquatic vegetation inventory was produced for Greek lakes, and primary results showed that the presence/absence of aquatic plant communities and the community composition in freshwater lakes can be utilized to assess the pressure of eutrophication on lake ecosystems.

Taxonomic reference: Euro+Med (2006–).

Abbreviations: MNT = Mean number of taxa; WFD = Water Framework Directive.

Keywords
aquatic plant, charophyte, ecological status, eutrophication, Greece, lake, macrophyte, phytosociology, plant community, vegetation

Introduction

Freshwater ecosystems are among the most threatened ecosystems around the world (Sala et al. 2000; Foley et al. 2005; Dudgeon et al. 2006). Overexploitation, water pollution, flow modification, destruction or degradation of habitats, and exotic species invasions are the five main drivers of biodiversity loss in freshwater ecosystems (Dudgeon et al. 2006). The European Union addressed the vulnerability of freshwater ecosystems with the adoption of the European Water Framework Directive (WFD, European Commission 2000). In this frame-
work, the monitoring of aquatic plant communities was proposed as a key element in order to assess the ecological status of freshwater ecosystems, as macrophytes play a significant role in determining the structure and functions of lake ecosystems by influencing environmental conditions, nutrient cycling, and biotic assemblages and interactions (Carpenter and Lodge 1986; Jeppesen et al. 1997; Engelhardt and Ritchie 2001). As a result, most of the monitoring and assessment systems developed by European countries utilise rankings in the tolerance and sensitivity of macrophyte taxa to eutrophication (Kolada et al. 2014; Poikane et al. 2018). The monitoring of aquatic macrophytes in Greek freshwater ecosystems, in the context of the Greek National Water Monitoring Network (GNWMN) under the WFD, began in 2013 (Zervas et al. 2018).

The number of floristic and phytosociological investigations in freshwater ecosystems within Greece has increased during the past three to four decades (Sarika-Hatzinikolaou et al. 2003; Sarika et al. 2005). Also publications containing phytosociological data for lacustrine aquatic plant communities have accumulated over time, but remain scarce and not evenly distributed across the country: Gradstein and Smittenberg (1977: western Crete), Lavrentiades and Pavlidis (1985: Lake Mikri Prespa), Papanastagiou (1990: various lakes in Northern Greece), Bergmeier (2001: seasonal pools in the island of Gavdos), Sarika-Hatzinikolaou et al. (2003: seven lakes in Epirus), Grigoriadis et al. (2005: Agras wetland), Dimopoulos et al. (2005: Kalodiki marsh); Zotos (2006: Lakes Trichonida and Lysimachia), Fotiadis et al. (2008: Lake Climaditida), and Pirini (2011: Lakes Vegoritida and Petres). These studies provide important information about aquatic vegetation in Greece, but the older ones do need to be revised and updated. Furthermore, research gaps remain in the country, i.e. a number of important lakes remain unsurveyed.

Taking into consideration all of the above information, the main objectives of this study are (i) to contribute to the knowledge of European freshwater lake ecosystems with new and updated country-wide information on the aquatic plant communities found in the main Greek freshwater lakes, and (ii) to investigate the relationship between the distribution patterns of macrophyte communities and environmental parameters indicating increased levels of eutrophication and altered hydro-morphological conditions.

### Study area

The study covers 18 lakes (Table 1; Figure 1) selected for GNWMN monitoring of aquatic macrophytes (Mavromati et al. 2017; Zervas et al. 2018). While the studied lakes are scattered over the Greek mainland, most of them are clustered in the west and north-central part of the country, differing in altitude, size, water depth, and local climatic conditions within their catchment area (Table 1). Of the three transboundary lakes (Doirani, Megali Prespa, Mikri Prespa) only their Greek areas were studied.

### Methods

**Vegetation and environmental data**

Each lake was surveyed once in 2013–2016 during the main growing season (May to September) (Table 1). In all lakes, the belt transect-mapping method was applied

### Table 1. Overview of the geographical, geometric and climatic characteristics of the studied lakes. Asterisks mark transboundary lakes, for which the characteristics refer to their part in Greece. Climatic characteristics have been collected by the European Climate Assessment & Dataset (Klein Tank et al. 2002). Average annual temperature and annual precipitation values have been calculated on the basis of available data during the period 1995-2005.

| No | Lake          | Centroid Latitude (N) | Centroid Longitude (E) | Mean Altitude (masl) | Area (km²) | Mean-Max depth (m) | Aver. Annual Temp. (°C) | Annual Precipitation (mm) | Climate zone (Köppen & Geiger) | Survey period | No of transects/relevés recorded |
|----|---------------|------------------------|------------------------|----------------------|------------|---------------------|-------------------------|---------------------------|---------------------------|----------------|--------------------------------|
| 1  | Volvi*        | 40.67740               | 23.47368               | 37                   | 75.5       | 13-28               | 15.6                    | 458                       | Csa                       | Aug 2016       | 20 / 317                      |
| 2  | Doirani*      | 41.23853               | 22.76487               | 146                  | 30.7       | 4-8                 | 14.3                    | 453                       | Cfa                       | Aug 2016       | 10 / 173                      |
| 3  | Vegoritida    | 40.74464               | 21.79442               | 577                  | 46.5       | 25-52               | 11.5                    | 530                       | Cfsf                      | June 2016      | 20 / 509                     |
| 4  | Petres        | 40.72604               | 21.69672               | 573                  | 12         | 3-6                 | 11.5                    | 562                       | Cfsf                      | June 2016      | 16 / 227                     |
| 5  | Zazari        | 40.62507               | 21.54690               | 600                  | 3          | 5-8                 | 11.5                    | 595                       | Cfsf                      | July 2016      | 12 / 124                     |
| 6  | Chimaditida   | 40.59258               | 21.56585               | 592                  | 9.1        | 1-5                 | 11.5                    | 595                       | Cfsf                      | July 2016      | 16 / 239                     |
| 7  | Kastoria      | 40.52269               | 21.30080               | 627                  | 31.2       | 4-9                 | 11.4                    | 697                       | Cfsf                      | Aug 2014       | 20 / 312                     |
| 8  | Megali Prespa* | 40.85057              | 20.98875               | 845                  | 39.4       | -16-26              | 10.2                    | 750                       | Cfsf                      | Aug 2015       | 12 / 206                     |
| 9  | Mikri Prespa* | 40.77031               | 21.10128               | 850                  | 44.7       | 4-10                | 10.2                    | 728                       | Cfsf                      | Aug 2015       | 15 / 294                     |
| 10 | Pamvotida     | 39.66270               | 20.88518               | 469                  | 22.6       | 5-12                | 13.2                    | 1081                      | Csa                       | Sept 2013      | 20 / 74                      |
| 11 | Anavrias      | 38.75113               | 21.77941               | 20                   | 13.5       | 22-54               | 17.3                    | 930                       | Csa                       | June 2014      | 20 / 331                     |
| 12 | Ozeros       | 38.63538               | 21.22294               | 24                   | 10.5       | 4-7                 | 17.2                    | 931                       | Csa                       | June 2014      | 20 / 178                     |
| 13 | Lysimachia    | 38.56234               | 21.37665               | 15                   | 13         | 4-8                 | 17.1                    | 909                       | Csa                       | June 2014      | 20 / 215                     |
| 14 | Trichonida    | 38.57309               | 21.54813               | 16                   | 93.4       | 30-56               | 17.1                    | 902                       | Csa                       | July 2015      | 20 / 792                     |
| 15 | Paralimni     | 38.45862               | 23.35285               | 37                   | 10.6       | 5-8                 | 17.5                    | 527                       | Csa                       | July 2014      | 20 / 503                     |
| 16 | Yliki         | 38.39764               | 23.27973               | 75                   | 22.5       | 22-34               | 17.5                    | 527                       | Csa                       | July 2014      | 20 / 29                      |
| 17 | Feneos        | 37.92861               | 22.28513               | 872                  | 0.5        | 10-29               | 11.5                    | 862                       | Csab                      | Aug 2014       | 10 / 373                     |
| 18 | Kourna        | 35.33180               | 24.27776               | 16                   | 0.6        | 15-22               | 18.2                    | 831                       | Csac                      | May 2014       | 14 / 794                     |
In order to define the vegetation types in the most objective manner possible, the relevés were subjected to a number of hierarchical cluster analyses. Extremely rare taxa, i.e. recorded in one to three out of 5690 plots, were excluded from the analyses in order to reduce “noise” in the data. DAFOR abundance classes were translated to their average percentage abundance values as follows: Dominant = 87.5%, Abundant = 50%, Frequent = 17.5%, Occasional = 5.5% and Rare = 0.5% (CEN 2007). Species abundances were chord distance-based transformed (Legendre and Galacher 2001). The transformed dataset was then subjected to cluster analysis with the use of flexible beta linkage method with b = -0.25 (Lance and Williams 1967) and Bray-Curtis dissimilarity (Bray and Curtis 1957). Elbow and Average Silhouette methods (Kaufman and Rousseeuw 1990), and NbClust statistic (Charrad et al. 2014) were used to assist in the determination of the optimal number of clusters for the dataset. Finally, diagnostic taxa were determined by indicator species analysis (Dufrene and Legendre 1997; De Cáceres et al. 2012), using the indicators function, in order to finalize the number of clusters corresponding to distinct vegetation types, and describe the best combination of indicator species for each vegetation type.

Due to the overall low number of common taxa among the resulting clusters, the hierarchic dendrogram that was produced was not able to successfully group all vegetation types into meaningful syntaxa, thus we proceeded with an additional cluster analysis. The synoptic table, which contained the clusters representing our dataset, was integrated into a dataset of clusters representing the types of Greek aquatic vegetation published in the past (bibliography in Suppl. material 1) and was processed again using the flexible beta linkage method and Bray-Curtis dissimilarity. The aim of including these vegetation types from the literature within our dataset was to support the present syntaxonomical decisions. The syntaxonomy of higher syntaxa (alliances, orders and classes) in the current study follows, with few exceptions, Mucina et al. (2016).

Depth distribution for each vegetation type was calculated and presented. The distribution of higher-rank syntaxa for each lake was also computed on the basis of the number of relevés per syntaxon in proportion to the total number of relevés in each lake. Calculations were summarized at the level of class for most of the vegetation types, except the ones belonging to the *Potamogetontetra* which were divided at the level of alliance, owing to the high variation in this class with different life forms. Finally, a multiple linear regression model was applied to assess the relation between aquatic vegetation patterns, as expressed by the abundance of higher-rank syntaxa, and environmental parameters in each lake. Pearson’s correlation coefficient (R) and p-value (p) of the model were assessed.

All analyses were performed with the use of vegan (Oksanen et al. 2018), cluster (Maechler et al. 2018), factoextra (Kassambara and Mundt 2017), NbClust (Charrad et al. 2014), indicspecies (De Cáceres and Legendre 2009), and tidyverse (Wickam 2017) R packages in R environment version 3.5.2 (R Core Team 2018).
Results and discussion

Species composition

The total number of taxa (vascular plants and macroalgae species) recorded in the studied lakes was 99. The most species-rich among the 30 different plant families were Characeae (12%), Cyperaceae (12%) and Potamogetonaceae (10%), followed by Hydrocharitaceae (7%), Lamiales (6%) and Poaceae (6%). Hydrophytes were the dominant life form (55% of total species) followed by hemicyryptophytes (25%) and geophytes (19%). The most prominent chorological element was the Cosmopolitans (26%), followed by Paleotemperate (15%), European-SW Asians (15%) and Circumtemperate (14%). Most of the taxa (80 out of 99) were recorded with frequencies of less than 1%, i.e. they were found in fewer than 57 plots out of all 5,690. The most frequent taxa (found in more than 500 plots) were Myriophyllum spicatum (29.3%), Phragmites australis (27.2%), Ceratophyllum demersum (25.1%), Vallisneria spiralis (23%), Stuckenia pectinata (22.5%) and Najas marina (14.3%). Twenty-six out of 99 taxa were recorded in three or fewer plots (taxon frequencies for each lake are summarized in Suppl. material 2).

Vegetation classification

Cluster analysis and subsequent tests resulted in 46 different vegetation types for interpretation (see Suppl. material 3 for Elbow, Average Silhouette and NbClust results, and Suppl. material 4 for produced dendrogram). Due to the survey methodology used, i.e. consecutive relevés distributed along a depth gradient at equal depth intervals, a number of the resulting vegetation types correspond to transitional ecotonal stands. These vegetation types were retained in the synoptic tables and are described in the text so as to present a more comprehensive picture of the spatial and ecological patterns of vegetation differentiation within the studied lakes. For syntaxonomic purposes, they may well be merged with an adjacent vegetation type. The diagnostic species for each vegetation type were selected from the results of the indicator species analysis as those combinations that reached a higher Indicator Value, while maintaining high prediction power and sensitivity (De Cáceres et al. 2012) (see Suppl. material 5 for all diagnostic taxa parameters). Diagnostic and accompanying species for each vegetation type are given in Tables 2–4. Short descriptions of the ecology (structure, water-depth preference etc.), the floristic composition and the distribution for each vegetation type are presented at the following paragraphs (see Suppl. material 6 for summary of vegetation types in all lakes). Syntaxonomic remarks that led to their final syntaxonomic assignment (Table 5) are also presented.

Class 1. Plantaginetea majoris

Syntaxon 1.1. Phyla nodiflora community (Code PhN, Table 2, Mean number of taxa MNT = 2.4)

Appearance and habitat: Sparse temporarily submerged carpets, dominated by Phyla nodiflora, a perennial herb of prostrate growth, covering periodically flooded shores. Phyla nodiflora is a cosmopolitan pioneer herb that grows prolifically in floodplain wetlands with periodical flooding of short duration (Sharma and Singh 2013). Other aquatic macrophytes rapidly colonizing flooded areas, such as Myriophyllum spicatum and Vallisneria spiralis, can also be found in this community.

Diagnostic taxa (% constancy): Phyla nodiflora (100%).

Distribution: Amvrakia, Yliki.

Syntaxonomic remarks: No association dominated by Phyla nodiflora was found in the European literature. An association of Phyla nodiflora growing together with Kyllinga peruviana (Kyllingo-Phylteum nodiflorae Vanden Berghen 1990) (De Foucault et al. 2013) was described in West African temporarly inundated coastal dune slacks, another with Paspalum vaginatum (Lippio nodiflorae-Paspaletum vaginati Galán de Mera, Linares, Campos and Vicente 2009) in South American saltwater influenced grasslands on the Pacific coast (Galán de Mera et al. 2009). In publications from the western Mediterranean basin (e.g. Brullo and Scandrello 2006; Ninot et al. 2011) an association of Phyla nodiflora growing in littoral grassy plains together with Panicum repens (Lippio nodiflorae-Panicetum repentin O. Bolös 1957) has been described, but our community differs as Panicum repens is absent. Our material is insufficient to provide a firm basis for describing a new association. We do not follow Mucina et al. (2016) who treat the perennial Phyla nodiflora as a diagnostic species of the class Isoeto-Nanojuncetea, defined as pioneer ephemeral vegetation in periodically flooded freshwater habitats. We assign the Phyla nodiflora community described here to the order Paspalo-Heleocholelatia and to the alliance Paspalo-Agrostion semiverticillati instead, which comprises Mediterranean-subtropical temporarily inundated, disturbed, perennial grass-herblands rich in stoloniferous plants of tropical and subtropical distribution.

Syntaxon 1.2. Paspalo distichi-Agrostietum verticillatae (Code PD, Table 2, MNT = 3.1)

Appearance and habitat: Emerged and floating mats of Paspalum distichum colonizing exposed areas of wet ground that may be temporarily shallowly inundated. Paspalum distichum is a perennial grass, originating from tropical America, which is widely established in riparian habitats of the Mediterranean basin, often forming monotypic stands (Aguiar et al. 2005).

Diagnostic taxa (% constancy): Paspalum distichum (100%).

Distribution: Doirani, Lysimachia, Paralimni, Trichonida and Vegoritida.
### Table 2. Synoptic table of the identified associations and communities belonging to Classes *Plantaginetea majoris*, *Phragmito-Magnocaricetea* and *Lemnetae*. Taxa constancy in percentage and their average abundance class (r = 0-1%, + = 2-5%, 1 = 6-20%, 2 = 21-40%, 3 = 41-60%, 4 = 61-80%, 5 = 81-100%) superscripted are shown. Companion taxa with less than 20% constancy are shown at the end of the Table. Diagnostic taxa for each vegetation type are marked in bold (see relevant text and Table 5 for vegetation type codes).

| Vegetation type code | PIN | PD | PA | PAE | SL | TD | TL | TA | BU | LM | UV | CD | CDE | CDMS |
|----------------------|-----|----|----|-----|----|----|----|----|----|----|----|----|-----|-----|
| PLANTAGINETA        |     |    |    | 100 |    |    |    |    |    |    |    |    |     |     |
| Physa nivalis       | 100 |    | 5  | 1   |    | 6  |    |    |    |    |    |    |     |     |
| Paspalum distichum  |     |    |    | 100 |    | 11 |    |    |    |    |    |    |     |     |
| PHRAGMITO-MAGNOCARICETEA |
| Phragmites australis | 14  | 100 | 97 | 78 | 84 | 6 | 81 | 30 | 28 | 20 | 11 | 64 | 7 | 1 |
| Schoenoplectus lacustris | 5  | 1  | 100 | 1  | 20 | 1  |    |    |    |    |    |    |     |     |
| Typha domingensis    | 10  | 2  | 7  | 50 | 100 | 1 |    |    |    |    |    |    |     |     |
| Typha latifolia      | 10  | 7  | 21 | 6  | 100 | 8 |    |    |    |    |    |    |     |     |
| Typha angustifolia   | 1  | 6  | 6  | 100 | 1 |    |    |    |    |    |    |    |     |     |
| Butomus umbellatus   |     |    |    | 100 | 1 |    |    |    |    |    |    |    |     |     |
| Schoenoplectus litoralis |    |    |    | 36 | 1 |    |    |    |    |    |    |    |     |     |
| Alisma plantago-aquatica |    |    |    | 12 |    |    |    |    |    |    |    |    |     |     |
| Carex pseudocyperus  | 1  |    |    | 30 | 1 |    |    |    |    |    |    |    |     |     |
| Juncus subnodulosus  |     |    |    | 30 |    |    |    |    |    |    |    |    |     |     |
| Mentha aquatica      | 5  | 4 | 6  | 1 | 73 | 1 |    |    |    |    |    |    |     |     |
| Lythrum salicaria    |     |    | 4 | 1 | 73 | 1 |    |    |    |    |    |    |     |     |
| Eleocharis palustris  | 1  | 4 | 6  | 1 | 20 | 1 |    |    |    |    |    |    |     |     |
| Stachys palustris     | 1  | 4 | 6  | 1 | 73 | 1 |    |    |    |    |    |    |     |     |
| Sparganium erectum   | 5  |    |    | 12 | 1 |    |    |    |    |    |    |    |     |     |
| LEMNATAE             |     |    |    | 100 | 30 | 17 |    |    |    |    |    |    |     |     |
| Lemna minor          | 5  | 1 | 11 | 1 | 100 | 30 | 17 |    |    |    |    |    |     |     |
| Lemna gibba          |     |    |    | 44 | 1 |    |    |    |    |    |    |    |     |     |
| Azolla filiculoides  | 1  | 4 | 1 | 73 | 1 |    |    |    |    |    |    |    |     |     |
| Spirodela polyrhiza  | 1  | 4 | 1 | 37 | 1 | 15 | 1 |    |    |    |    |    |     |     |
| Salvinia natans      | 1  | 4 | 1 | 19 | 1 | 15 | 1 |    |    |    |    |    |     |     |
| Utricularia vulgaris + australis | 1  | 4 | 1 | 100 | 1 |    |    |    |    |    |    |    |     |     |
| Ceratophyllum demersum | 6 | 11 | 23 | 39 |    |    |    |    |    |    |    |    |     |     |
| Ceratophyllum submersum | 1 | 4 | 6 | 1 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |    |     |
| Hydrocharis morus-ranae | 1 | 4 | 12 | 1 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |     |
| Other taxa           |     |    |    | 100 | 10 | 20 |    |    |    |    |    |    |     |     |
| Myriophyllum spicatum | 60 | 10 | 31 | 14 | 39 | 78 | 43 | 100 | 10 | 8 | 19 | 100 | 1 | 100 |
| Stuckenia pectinata  | 31 | 71 | 28 | 1 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Vallisneria spiralis | 60 | 10 | 31 | 14 | 39 | 78 | 43 | 100 | 100 | 100 | 100 | 100 | 100 |
| Potamogeton lucens   | 5  | 1 | 1 | 83 | 1 | 13 | 12 |    |    |    |    |    |     |     |
| Rumex palustris      | 10 | 1 | 4 | 12 | 12 |    |    |    |    |    |    |    |     |     |
| Potamogeton nodosus  | 20 | 10 | 1 | 17 | 1 |    |    |    |    |    |    |    |     |     |
| Najas marina         | 5  | 17 |    | 23 |    |    |    |    |    |    |    |    |     |     |
| Zannichellia palustri | 1 | 4 | 20 | 1 |    |    |    |    |    |    |    |    |     |     |
| Ludwigia peploides   | 23 | 5 | 23 |    |    |    |    |    |    |    |    |    |     |     |
| Chara globularis     | 1  | 23 | 23 | 1 |    |    |    |    |    |    |    |    |     |     |
| Cladophora glomerata | 37 | 1 | 49 | 17 | 17 |    |    |    |    |    |    |    |     |     |
| Nitella obscura      | 14 | 1 | 14 | 1 |    |    |    |    |    |    |    |    |     |     |

**Syntaxonomic remarks:** Of the four different associations with *Paspalum distichum* described in the western Mediterranean (*Paspalo distichico-Agrostietum verticilla- tum* Braun-Blanq. 1936; *Ranunculo scelerati-Paspaleetum paspalodis* Rivas Goday 1964 corr. Peinado, Bartolome, Martinez-Parras and Ollala 1988; *Heliotropio supini-Paspaleetum paspalodis* Martinez-Parras, Peinado, Bartolome and Molero 1988; *Paspaleetum dilatato-distichici* Herrera and F. Prieto in T.E. Diaz and F. Prieto 1994) (Jose et al. 1988; Rivas-Martinez et al. 2001; Neto et al. 2009), we choose to assign our vegetation type as a variant of the first one, which is first in priority order if *P. distichum* dominance stands are treated as a single association. Zotos (2006) identified two communities with *Paspalum distichum* in his study of wetlands around lakes Trichonida and Lysimachia, including one dominated by *Paspalum distichum*. All the above-mentioned associations and communities have been grouped in the alliance *P. distichum*.
**Phragmites** - 

Class 2. *Phragmito-Magnocaricetea*

**Syntaxon 2.1. Phragmitetum communis** (Code PA, Table 2, MNT = 1.2)

Appearance and habitat: Extensive and dense (>50% cover) reed beds of *Phragmites australis*, the most commonly noticed and recorded association in most lakes. They cover major parts of the littoral zone, reaching down to 6m depth.

Diagnostic taxa (% constancy): *Phragmites australis* (100%).

Distribution: Pamvotida, Amvrakia, Kastoria, Lysimachia, Ozeros, Paralimni, Trichonida, Megali Prespa, Mikri Prespa, Volvi, Vegoritida, Zazari, Petres, Doirani and Chimadiotida.

Syntaxonomic remarks: This association, widespread across all bioclimatic zones of Eurasia, matches with what has been identified as *Phragmitetum communis* (australis) or *Scirpo-Phragmitetum* in numerous publications in Greece (Drosos et al. 1996; Sarika-Hatzinikolaou et al. 2003; Grigoriadis et al. 2005; Zotos 2006) and Europe (Preising et al. 1990; Šumberová et al. 2011a; Landucci et al. 2013; Jenačković 2017; Lastrucci et al. 2017).

Syntaxon 2.2. Transitional stands of *Phragmites australis* (Code PAE, Table 2, MNT = 3.4)

Appearance and habitat: Stands of *Phragmites australis* with floristic composition similar to the preceding cluster but with lower *Phragmites* cover (<50%). They are found at the edges of dense reed beds, down to 6m depth, where the *Phragmitetum communis* progressively gives way to, or is interconnected with, aquatic communities such as *Cladophoretum glomeratae*, *Najadetum marinae*, *Lemnetum minoris*, *Ceratophylletum demersi*, *Potamogeton pectinati-Myriophyllum spicati* etc. Due to their sparse cover, other riparian and aquatic plants of the above-mentioned or other plant communities colonize the open areas among and beneath the reeds.

Diagnostic taxa (% constancy): *Phragmites australis* (97%), *Cladophora glomerata* (48.3%), *Najas marina* (17.3%), *Nitellopsis obtusa* (13.8%).

Distribution: Pamvotida, Feneos, Kastoria, Megali Prespa, Volvi, Vegoritida, Zazari, Petres and Chimadiotida.

Syntaxonomic remarks: This cluster falls within the range of variation of the *Phragmitetum communis*.

Syntaxon 2.3. *Scirpetum lacastris* (Code SL, Table 2, MNT = 5.6)

Appearance and habitat: Dense stands of club-rush *Schoenoplectus lacustris* (>25% cover) and low presence of other helophytes (*Phragmites*, *Sparganium* and *Typha* spp.). In lacustrine ecosystems, it often forms a zone in mostly shallow waters down to 1m deep, sensitive to wave action, between the open water and the dense reed-bed areas dominated by other species, like *Phragmites australis*.

Diagnostic taxa (% constancy): *Schoenoplectus lacustris* (100%), *Phragmites australis* (78%).

Distribution: Volvi, Paralimni, Trichonida, Mikri Prespa, Petres and Chimadiotida.

Syntaxonomic remarks: Matches the descriptions of this association (sometimes under the name *Schoenoplectetum lacustris*) from publications in Greece (Sarika-Hatzinikolaou et al. 2003; Dimopoulos et al. 2005; Zotos 2006; Fotiadis et al. 2008) and in Europe (Preising et al. 1990; Lukács et al. 2009; Šumberová et al. 2011a; Landucci et al. 2013; Jenačković 2017).

Syntaxon 2.4. *Typhetum domingensis* (Code TD, Table 2, MNT = 3.1)

Appearance and habitat: Dense stands of Mediterranean cattail *Typha domingensis* (>25% cover) and low presence of other helophytes (*Phragmites*, *Sparganium*, other *Typha* spp.). *Typha domingensis* stands, like other *Typha* communities, are usually colonizing next to the extensive *Phragmites australis* reed zone, in waters down to 4m deep, under low water fluctuation regime.

Diagnostic taxa (% constancy): *Typha domingensis* (100%).

Distribution: Trichonida and Chimadiotida.

Syntaxonomic remarks: Matches the descriptions of this association in European publications (Biondi and Bagella 2005; Landucci et al. 2013; Jenačković 2017). In Greece, Zotos (2006) recorded two vegetation types in lake Trichonida, one with *Typha domingensis* alone and another with co-dominance of *Phragmites australis*. These are variants of the *Typhetum domingensis*.

Syntaxon 2.5. *Typhetum latifoliae* (Code TL, Table 2, MNT = 2.3)

Appearance and habitat: Dense stands of the cattail *Typha latifolia* (>25% cover) and low presence of other helophytes (*Phragmites*, *Sparganium* and other *Typha* spp.). *Typha latifolia*, like other *Typha* spp., colonizes openings next to the extensive *Phragmites australis* reed zone, in waters down to 2m deep, under low water fluctuation regime.

Diagnostic taxa (% constancy): *Typha latifolia* (100%), *Myriophyllum spicatum* (78%).

Distribution: Pamvotida, Feneos, Vegoritida and Doirani.

Syntaxonomic remarks: Matches the descriptions of Greek (Sarika-Hatzinikolaou et al. 2003; Fotiadis et al. 2008) and European publications (Preising et al. 1990; Šumberová et al. 2011a; Landucci et al. 2013; Jenačković 2017). Lower cover of *Typha latifolia* (<25% cover) was recorded in some plots, possibly due to sub-optimal water fluctuation conditions often prevailing in Mediterranean lakes (Coops et al. 2003; Flores and Barone 2005).
Syntaxon 2.6. Typhetum angustifolii (Code TA, Table 2, MNT = 2.1)

Appearance and habitat: Dense stands of the cattail Typha angustifolia (>25% cover) and low presence of other helophytes (Phragmites, Sparganium and other Typha spp.). Typha angustifolia, like Typha latifolia and T. domingensis, forms clonal rhizomatous stands next to Phragmites australis reed-beds, in waters to 2m deep, under low water fluctuation regime.

Diagnostic taxa (% constancy): Typha angustifolia (100%).

Distribution: Feneos and Mikri Prespa.

Syntonymic remarks: Matches the descriptions from Greek (Sarika-Hatzinikolaou et al. 2003; Dimopoulos et al. 2005, as Typho-Phragmitetum typhetosum angustifoliac; Fotiadis et al. 2008) and other European publications (Preising et al. 1990; Šumberová et al. 2011a; Landucci et al. 2013; Jenáckov 2017). Lower cover of Typha angustifolia (<25% cover) was recorded in some plots which, as in the Typhetum latifolii, may be due to higher than optimal water fluctuation in Mediterranean lakes (Coops et al. 2003; Flores and Barone 2005).

Syntaxon 2.7. Butometum umbellati (Code BU, Table 2, MNT = 4.5)

Appearance and habitat: Stands of partly submerged Butomus umbellatus, in open water littoral areas, down to 3m deep and with high water-transparency. It is characterized by the helophyte Butomus umbellatus (>25% cover) while other helophytes (Phragmites, Sparganium, Typha) occur with very low presence. A number of hydrophytes such as Myriophyllum spicatum and Vallisneria spiralis are constantly filling the gaps between these stands.

Diagnostic taxa (% constancy): Butomus umbellatus (100%), Myriophyllum spicatum (100%).

Distribution: Trichonida.

Syntonymic remarks: This association has been identified in various parts of Europe (Preising et al. 1990; Nagy et al. 2009; Šumberová et al. 2011a; Stepien et al. 2015), mostly described from shallower waters than in our study, accompanied by helophytes and lemnids. To our knowledge, a distinct Butomus umbellatus community had not been identified before in Greece.

Class 3. Lemnetea

Syntaxon 3.1. Lemnetum minoris (Code LM, Table 2, MNT = 5.8)

Appearance and habitat: Mats of the free-floating duckweed Lemma minor (>50% cover), accompanied by less abundant lemnids, such as Spirodela polyrhiza, Azolla filiculoides and other Lemma spp., can be found in the littoral zone of still and relatively nutrient-rich freshwater bodies, in very shallow waters 0–1m deep, in spots protected against wave action.

Diagnostic taxa (% constancy): Lemma minor (100%), Azolla filiculoides (73%).

Distribution: Doirani, Vegoritida and Chinariditida.

Syntonymic remarks: Matches the descriptions of this widespread association from Greece (Lavrentiades and Pavlidis 1985; Papastergiadou 1990; Zotos 2006) and elsewhere in Europe (Goldyn et al. 2005; Klosowski and Jabłońska 2009; Šumberová 2011b; Felzines 2012).

Syntaxon 3.2. Lemno-Utricularietum and Utricularietum australis (Code UV, Table 2, MNT = 5.2)

Appearance and habitat: Open to fully closed submerged carpets of the free-floating carnivorous bladderworts Utricularia vulgaris or Utricularia australis (>25% cover), with other taxa found in low numbers. As the bladderworts cannot be identified with certainty if not in flower, both species are likely to be included. Frequent present at the surface of the water occur Hydrocharis morsus-ranae and lemnids, like Lemna minor, Lemna gibba, Spirodela polyrhiza etc., while Ceratophyllum demersum may occur in lower strata of the water column. Vegetation of free-floating bladderworts can be found in very shallow, down to 1m deep, mesotrophic to eutrophic waters protected against wave action.

Diagnostic taxa (% constancy): Utricularia vulgaris + U. australis (100%).

Distribution: Doirani, Pamvotida, Petres and Chinariditida.

Syntonymic remarks: Matches the descriptions of this widespread association from Greece (Sarika-Hatzinikolaou et al. 2003; Pirini 2011, with Utricularia vulgaris and Chara vulgaris) and elsewhere in Europe (Šumberová 2011b; Felzines 2012; Džigurski et al. 2016; Cvijanović et al. 2018).

Syntaxon 3.3. Ceratophylletum demersi (Code CD, Table 2, MNT = 1.5)

Appearance and habitat: Extensive (>50% cover) carpets of Ceratophyllum demersum, a free-floating aquatic macrophyte in variable habitat conditions. Due to its ability to grow well in turbid water, under poor light conditions, it spreads rapidly and may cover the whole water column, possibly limiting the growth of other hydrophytes. While it thrives mostly in shallow waters, it may colonize the full depth range of aquatic macrophytes (in Greece 0–13m).

Diagnostic taxa (% constancy): Ceratophyllum demersum (100%).

Distribution: Amvrakia, Kastoria, Lysimachia, Ozeros, Paralimni, Ylikri, Trichonida, Megali Prespa, Mikri Prespa, Voltvi, Vegoritida, Petres, Doirani and Chinariditida.

Syntonymic remarks: Matches the descriptions in European publications (Goldyn et al. 2005; Šumberová 2011b; Felzines 2012; Lastrucci et al. 2014, 2015; Džigurski et al. 2016; Cvijanović et al. 2018). In Greece, Papastergiadou (1990) and Dimopoulos et al. (2005) identified this association with similar floristic composition, while Sarika-Hatzinikolaou et al. (2003) described a more variable and perhaps composite association, with higher constancies of other Lemneta and Potamogetoneta diagnostic taxa (Lemma minor, Spirodela polyrhiza, Hydrocharis morsus-ranae, Myriophyllum spicatum and Potamogeton...
crispus). Gradstein and Smittenberg (1977) recorded a community in which 
Ceratophyllum demersum co-occurs with Potamogeton trichoides.

Syntaxon 3.4. Transitional stands of Ceratophyllum demersum (Code CDE, Table 2, MNT = 3.5)

Appearance and habitat: Similar to the Ceratophyllum demersi but with less cover (<50%) of Ceratophyllum, are found at the edges of the dense Ceratophyllum stands, in waters down to 13m deep, where the Ceratophyllum demersi progressively transitions into other macrophytic communities (Phragmitetum communis, Lemnetum minoris, Potamogetono pectinati-Myriophylletum spicati, Potametum pectinati etc.). Other macrophytes like Phragmites australis, Lemna minor, Salvinia natans, Spirodela polyrhiza, Myriophyllum spicatum and Stuckenia pectinata colonize the openings.

Diagnostic taxa (% constancy): Ceratophyllum demersum (100%), Phragmites australis (64%) Distribution: Volvi, Doirani, Kastoria, Lysimachia, Ozeros, Mikri Prespa, Vegoritida and Chichaditida.

Syntaxonomic remarks: This cluster is a variant of the Ceratophyllum demersi.

Syntaxon 3.5. Ceratophyllum demersum-Myriophyllum spicatum community (Code CDMS, Table 2, MNT = 2.6)

Appearance and habitat: This cluster represents a transition between Ceratophyllum demersi and Potamogetono pectinati-Myriophylletum spicati found at the edges of these communities, in waters down to 6m deep, where Ceratophyllum demersum becomes sparse and Myriophyllum spicatum stands are able to colonize the open spots.

Diagnostic taxa (% constancy): Ceratophyllum demersum (100%), Myriophyllum spicatum (100%)

Distribution: Amvrakia, Paralimnion, Yiliki, Trichonida, Megali Prespa, Mikri Prespa, Volvi, Vegoritida and Doirani.

Syntaxonomic remarks: These complex stands may be assigned to any of the two associations depending on species' prevalence.

Class 4. Potamogetonetea: Alliance 1. Potamogetonion

Syntaxon 4.(1.1). Potamogetono pectinati-Myriophylletum spicati (Code MS, Table 3, MNT = 2.4)

Appearance and habitat: Dense stands (mostly >50% cover) of the water-milfoil Myriophyllum spicatum, a submerged macrophyte with a broad ecological range, common even in disturbed sites. It roots at the lake bottom and reaches the water surface to emerge its inflorescence. These stands colonize waters down to 6m deep, provided water transparency is sufficiently high (chiefly mesotrophic conditions).

Diagnostic taxa (% constancy): Myriophyllum spicatum (100%). Distribution: Amvrakia, Feneos, Paralimnion, Yiliki, Trichonida, Megali Prespa, Mikri Prespa, Volvi, Vegoritida, Petres and Doirani.

Syntaxonomic remarks: Matches the descriptions of this association, mostly under the name of Myriophylle-
tum spicati, in publications from Greece (Papastergiadou 1990; Sarika-Hatzinikolaou et al. 2003; Dimopoulos et al. 2005; Fotiadis et al. 2008; Pirini 2011) and throughout Europe (Goldyn et al. 2005; Klosowski 2006; Šumberová 2011a; Džigurski et al. 2016). One possible reason for occasional lower cover of Myriophyllum (<50% cover) may be light limitations in deeper plots (Middelboe and Markager 1997; Klosowski 2006).

Syntaxon 4.(1.1). 2. Potamogetonetum pectinati (Code SP, Table 3, MNT = 1.3)

Appearance and habitat: Dense stands (>50% cover) of Stuckenia pectinata (=Potamogeton pectinatus), a submerged aquatic plant quite tolerant of brackish and turbid fresh water, found in open water of various depth down to 1-4m if water transparency permits.

Diagnostic taxa (% constancy): Stuckenia pectinata (100%)

Distribution: Kastoria, Kourna, Trichonida, Volvi, Vegoritida, Petres and Doirani.

Syntaxonomic remarks: Matches the descriptions of this association from Greece (Papastergiadou 1990; Sarika-Hatzinikolaou et al. 2003; Pirini 2011) and elsewhere in Europe (Solińska-Górnicka and Symonides 2001; Hrivnák 2002; Melendo et al. 2003; Goldyn et al. 2005; Šumberová 2011a; Lastrucci et al. 2014; Cvijanović et al. 2018).

Syntaxon 4.(1.1).3. Transitional stands of Stuckenia pectinata (Code SPE, Table 3, MNT = 3.6)

Appearance and habitat: Stands of Stuckenia pectinata, similar in composition with the preceding cluster, but with lower cover of Stuckenia (<50%), were found at the edges of the dense Stuckenia stands, in waters down to 4m deep, in contact with other macrophyte communities such as the Phragmitetum communis, Potamogetono pectinati-Myriophylletum spicati etc., in openings with macrophytes such as Phragmites australis, Myriophyllum spicatum and Chara tomentosa.

Diagnostic taxa (% constancy): Stuckenia pectinata (96%), Phragmites australis (74%).

Distribution: Volvi, Doirani, Kastoria, Kourna, Vegoritida and Petres.

Syntaxonomic remarks: This cluster is a variant of the Potamogetonetum pectinati.

Syntaxon 4.(1.1).4. Stuckenia pectinata-Myriophylletum spicati community (Code SPMS, Table 3, MNT = 3.3)

Appearance and habitat: This cluster is transitional between Potamogetonetum pectinati and Potamogetonetea pectinati-Myriophylletum spicati, often found at the edges of the two associations, in waters down to 6m.

Diagnostic taxa (% constancy): Stuckenia pectinata (100%), Myriophylletum spicati (92%).

Distribution: Kastoria, Paralimnion, Trichonida, Volvi, Vegoritida and Doirani.

Syntaxonomic remarks: Relevés of this cluster are assignable to any of the two associations depending on species' dominance.
Table 3. Synoptic table of the identified associations and communities belonging to Class Potamogetonetea. Taxa constancy in percentage and their average abundance class (r = 0-1%, + = 2-5%, 1 = 6-20%, 2 = 21-40%, 3 = 41-60%, 4 = 61-80%, 5 = 81-100%) superscripted are shown. Companion taxa with less than 20% constancy are shown at the end of the Table.

| Vegetation type code | MS | SP | SPE | SPMS | PP | PCr | PV | PVMS | PL | PLMS | PoN | PCa | PoT | NMa | NMaE | NMi | NM | TN | NA | NL | NP | LP |
|----------------------|----|----|-----|------|----|----|----|------|----|------|-----|-----|-----|-----|------|----|----|----|----|----|----|----|
| Number of relevés    | 472| 866| 41  | 56   | 39 | 5  | 772| 167  | 116| 43   | 21  | 6   | 9   | 334 | 80   | 20 | 6   | 7   | 5  | 10 | 34 |
| Mean number of species | 2.4| 1.3| 3.6| 3.3 | 2.2| 2.4| 2.0| 2.8  | 2.4| 3.3  | 4.7 | 3.3| 6.1 | 1.8 | 3.4  | 6.7 | 4.3 | 5.4 | 1.2 | 4.8 | 2.0 |

**Diagnostic taxa for each vegetation type are marked in bold (see relevant text and Table 5 for vegetation type codes).**

### Potamogetonetum

| Taxon                                  | Number of relevés | Number in Table | Percentage constancy |
|----------------------------------------|-------------------|-----------------|----------------------|
| *Myriophyllum spicatum*                | 100               | 1               | 81-100%              |
| *Stuckenia pectinata*                  | 100               | 1               | 81-100%              |
| *Potamogeton perfoliatii*              | 100               | 1               | 81-100%              |
| *Vallisneria spiralis*                 | 20                | 1               | 21-40%               |
| *Potamogeton lucens*                   | 30                | 1               | 21-40%               |
| *Potamogeton nodosus*                  | 10                | 1               | 10-30%               |
| *Potamogeton compressus*               | 1                 | 1               | 10-30%               |
| *Potamogeton triochoides*              | 1                 | 1               | 10-30%               |
| *Najas marina*                         | 5                 | 1               | 21-40%               |
| *Najas minor*                          | 3                 | 1               | 10-30%               |
| *Trapa natans*                         | 5                 | 1               | 21-40%               |

#### Nymphaeion albae

| Taxon                                  | Number of relevés | Number in Table | Percentage constancy |
|----------------------------------------|-------------------|-----------------|----------------------|
| *Nymphaea alba*                        | 2                 | 1               | 100%                 |
| *Nuphar lutea*                         | r                 | 1               | 100%                 |
| *Nymphoides peltata*                   | r                 | 1               | 100%                 |
| *Lobelia dortmanna*                    | 3                 | 1               | 100%                 |
| *Parsicalis amphibia*                  | 3                 | 1               | 100%                 |

#### Other taxa

| Taxon                                  | Number of relevés | Number in Table | Percentage constancy |
|----------------------------------------|-------------------|-----------------|----------------------|
| *Phragmites australis*                 | 10                | 1               | 100%                 |
| *Butomus umbellatus*                   | 1                 | 1               | 100%                 |
| *Schoenoplectus lacustris*             | 3                 | 1               | 100%                 |
| *Typha latifolia*                      | 3                 | 1               | 100%                 |
| *Typha angustifolia*                   | 3                 | 1               | 100%                 |
| *Eleocharis mirifica*                  | 3                 | 1               | 100%                 |
| *Rorippa amphibia*                     | 3                 | 1               | 100%                 |
| *Lemna minor*                          | 3                 | 1               | 100%                 |
| *Lemna gibba*                          | 3                 | 1               | 100%                 |
| *Azolla filiculoides*                  | 3                 | 1               | 100%                 |
| *Spirodela polyrhiza*                  | 3                 | 1               | 100%                 |
| *Chara verticillata*                   | 3                 | 1               | 100%                 |

### Syntaxon 4.(1.5). Potamogetonetum perfoliati (Code PP, Table 3, MNT = 2.2)

Appearance and habitat: Submerged stands dominated (>25% cover) by the pondweed *Potamogeton perfoliatus*, accompanied with a lower abundance of *Myriophyllum spicatum*, *Stuckenia pectinata* and *Najas marina*. *Potamogeton perfoliatus* roots at lake bottom and produces emergent inflorescences. It forms extensive stands in waters down to 5m, provided water transparency is high (mostly under mesotrophic conditions).

Diagnostic taxa (% constancy): *Potamogeton perfoliatus* (100%).

Distribution: Kastoria, Megali Prespa, Volvi, Vegeritida, Zazari and Doirani.

### Syntaxon 4.(1.6). Potamogetonetum crispi (Code PCr, Table 3, MNT = 2.4)

Appearance and habitat: Submerged stands dominated (>25% cover) by *Potamogeton crispus*, accompanied at lower abundance by *Myriophyllum spicatum*, *Vallisneria spiralis* and *Najas marina*. Like *Potamogeton perfoliatus*, *P. crispus* forms extensive stands rooting at lake bottom down to 4m depth under usually meso- to eutrophic conditions.

Diagnostic taxa (% constancy): *Potamogeton crispus* (100%).
Distribution: Yiliki and Megali Prespa.

Syntaxonomic remarks: Matches the descriptions throughout Europe (Hrivnák 2002; Melendo et al. 2003; Goldyn et al. 2005; Šumberová 2011a; Lastrucci et al. 2014, 2015) and Greece (Papastergiadou 1990; Sarika-Hatzinikolaou et al. 2003; Grigoriadis et al. 2005).

Syntaxon 4.(1.7). Potamogetono-Vallisnerietum spiralis (Code PV, Table 3, MNT = 2.0)

Appearance and habitat: Dense carpets (>25% cover) of the submerged eel-grass *Vallisneria spiralis* covering the lake-bottom in areas with favourable light and nutrient conditions down to a depth of 10m. Sporadic *Myriophyllum spicatum* and other *Potamogeton* taxa root in small openings within the *Vallisneria spiralis* carpet, exploiting the water column above.

Diagnostic taxa (% constancy): *Vallisneria spiralis* (100%).

Distribution: Amvrakia, Feneos, Kastoria, Ozeros, Paralimni, Yiliki, Trichonida, Megali Prespa, Volvi, Vegoritida and Doirani.

Syntaxonomic remarks: Matches the descriptions of this apparently uncommon association scattered in Europe (Gabka 2002; Hutorowicz et al. 2006; Lastrucci et al. 2014) and Greece (Papastergiadou 1990; Grigoriadis et al. 2005; Pirini 2011). A similar association (*Ceratophyllum demersi-Vallisnerietum spiralis*) with higher constancy of *Ceratophyllum demersum* was identified in Serbia (Cvijanović et al. 2018).

Syntaxon 4.(1.8). *Vallisneria spiralis*-Myriophyllum spicatum community (Code PVMS, Table 3, MNT = 2.8).

Appearance and habitat: This cluster is transitional between the *Potamogetono-Vallisnerietum* and the *Potamogetono pectinati-Myriophylletum spicati*. If water transparency permits (mostly oligotrophic to mesotrophic conditions) such stands can be found in waters 10m deep.

Diagnostic taxa (% constancy): *Vallisneria spiralis* (100%), *Myriophyllum spicatum* (74%).

Distribution: Amvrakia, Feneos, Kastoria, Ozeros, Paralimni, Yiliki, Trichonida, Megali Prespa, Volvi, Vegoritida and Doirani.

Syntaxonomic remarks: The relevés can be assigned to either of the two associations depending on species’ dominance.

Syntaxon 4.(1.9). *Potamogetoneto lucentis* (Code PL, Table 3, MNT = 2.4)

Appearance and habitat: Dense stands (>25% cover) of the submerged pondweed *Potamogeton lucens* accompanied at lower abundance by *Myriophyllum spicatum*, *Vallisneria spiralis* and *Potamogeton nodosus*, colonizing waters down to a 6m depth when water transparency permits (usually under oligotrophic to mesotrophic conditions).

Diagnostic taxa (% constancy): *Potamogeton lucens* (100%).

Distribution: Paralimni and Yiliki.

Syntaxonomic remarks: Matches the descriptions in Greece (Gradstein and Smittenberg 1977; Papastergiadou 1990; Sarika-Hatzinikolaou et al. 2003; Dimopoulos et al. 2005) and throughout most of Europe (Preising et al. 1990; Hrivnák 2002; Melendo et al. 2003; Goldyn et al. 2005; Klosowski 2006; Šumberová 2011a).

Syntaxon 4.(1.10). *Potamogeton lucens*-Myriophyllum spicatum community (Code PLMS, Table 3, MNT = 3.3)

Appearance and habitat: This cluster is transitional between *Potamogetono pectinati-Myriophylletum spicati* and *Potamogetoneto lucentis*, characterized by a more or less equivalent constancy and abundance of the two characteristic species (*Myriophyllum spicatum*, *Potamogeton lucens*). It grows in waters down to 6m deep, where *Myriophyllum spicatum* stands become quite sparse and other hydrophytes, mostly *Potamogeton lucens*, occur in openings.

Diagnostic taxa (% constancy): *Myriophyllum spicatum* (98%), *Potamogeton lucens* (87%), *Phragmites australis* (30.3%).

Distribution: Paralimni, Megali Prespa and Mikri Prespa.

Syntaxonomic remarks: Relevés of this cluster can be assigned to either of the two associations according to the species’ dominance.

Syntaxon 4.(1.11). *Potamogetoneto denso-nodosi* (Code PoN, Table 3, MNT = 4.7)

Appearance and habitat: Open to fully closed (>25% cover) *Potamogeton nodosus* stands with floating leaves, accompanied at lower abundance by taxa such as *Myriophyllum spicatum*, *Potamogeton lucens* and *Najas marina*. *Potamogeton nodosus* forms extensive mats in still freshwater bodies down to 3m deep.

Diagnostic taxa (% constancy): *Potamogeton nodosus* (96%).

Distribution: Amvrakia, Feneos and Paralimni.

Syntaxonomic remarks: Matches the descriptions of this widespread but infrequent association (Melendo et al. 2003; Šumberová 2011a; Lastrucci et al. 2014; Džigurski et al. 2016; Cvijanović et al. 2018), which in Greece, so far only Papastergiadou (1990, as *Ranunculetum fluitantis* but with similar floristic composition) described in slow-flowing waters.

Syntaxon 4.(1.12). *Potamogetoneto compressi* (Code PCo, Table 3, MNT = 3.3)

Appearance and habitat: Dense stands (>25% cover) of the submerged pondweed *Potamogeton compressus* accompanied at lower abundance by taxa such as *Vallisneria spiralis*, *Stuckenia pectinata* and *Najas marina*. Its shallow root system is vulnerable to wave action, thus *Potamogeton compressus* forms limited stands in shallow (down to 2m deep) water near lake shorelines.

Diagnostic taxa (% constancy): *Potamogeton compressus* (100%).

Distribution: Kastoria.

Syntaxonomic remarks: Only a few publications described this association from Eurasia (Kuzmichev et al. 2008;
Borsukewych 2013; Chepinoga et al. 2013), which is rare and/or declining in Europe (Birkinshaw et al. 2013). There are no previous records of this association from Greece.

Syntaxon 4.(1.13). Potamogetonetum trichoidis (Code PT, Table 3, MNT = 6.1)

Appearance and habitat: Dense stands (>25% cover) of the submerged narrow-leaved pondweed Potamogeton trichoides, accompanied at lower abundance by taxa such as Myriophyllum spicatum, Ceratophyllum demersum and Lemna minor. Being quite variable, this vegetation type was found in meso-eutrophic waters down to 4m deep, where Potamogeton trichoides leaves spaces for a mix of other elodeid and lemnid aquatic macrophytes as well as helophytes.

Diagnostic taxa (% constancy): Potamogeton trichoides (67%), Ceratophyllum demersum (56%), Cladophora glomerata (56%), Myriophyllum spicatum (44.5%), Typha latifolia (44.5%).

Distribution: Kastoria, Lysimachia, Vegoritida, Doirani and Chimaditida.

Syntonomic remarks: Similar to the descriptions of Greek (Dimopoulous et al. 2005; Gradzad and Smittenberg 1977; Papastergiadou 1990; Sarika-Hatzinikolaou et al. 2003) and European publications (Preising et al. 1990; Hrvnák 2002; Melendo et al. 2003; Šumberová 2011a).

Syntaxon 4.(1.14). Najadetum marinae (Code NMa, Table 3, MNT = 1.8)

Appearance and habitat: Dense submerged carpets (>25% cover) of the naiad Najas marina accompanied at lower abundance by Potamogetonetea species such as Potamogeton perfoliatus, Myriophyllum spicatum and Vallieseria spiralis. Najas marina forms dense carpets on the bottom of still water bodies, down to 5m deep, under mesotrophic to eutrophic and even slightly brackish conditions.

Diagnostic taxa (% constancy): Najas marina (100%).

Distribution: Amvrakia, Kastoria, Kourna, Ozeros, Paralimni, Yliki, Trichonida, Megali Prespa, Mikri Prespa, Volvi, Petres and Doirani.

Syntonomic remarks: Described from Europe (Melendo et al. 2003; Šumberová 2011a; Lastrucci et al. 2014; Džigurski et al. 2016; Cvijanović et al. 2018) and Greece (Papastergiadou 1990) gathered a relevé dominated by Najas minor, accompanied by Zannichellia palustris, which was assigned to the Zannichellietum palustris.

Class 4. Potamogetonetea: Alliance 2. Nymphaeion albae

Syntaxon 4.(2.17). Trapetum natantis (Code TN, Table 3, MNT = 4.3)

Appearance and habitat: Open to closed (>25% cover) floating mats of the annual water caltrop Trapa natans, most often accompanied by Ceratophyllum demersum which tolerates poor light conditions. Nymphaeas such as Trapa natans are macrophytes that root at the bottom of still freshwater bodies, but most of their biomass, in particular most of the leaves, is floating on the water surface. Trapa occurs in waters down to 3m deep, limiting light levels for other submerged macrophytes underneath.

Diagnostic taxa (% constancy): Trapa natans (100%), Ceratophyllum demersum (100%).

Distribution: Kastoria and Megali Prespa.

Syntonomic remarks: The Trapetum natantis has been described in Greece, (Lavrentiades and Pavlidis 1985; Papastergiadou 1990) and Europe (Šumberová 2011a; Džigurski et al. 2016; Cvijanović et al. 2018).

Syntaxon 4.(2.18). Nymphaeetum albae (Code NA, Table 3, MNT = 5.4)

Appearance and habitat: Open to closed (>25% cover) floating vegetation mats of the water lily Nymphaea alba, most often accompanied by Ceratophyllum demersum which is undemanding in terms of light. Like other nymphaeas, Nymphaea alba is bottom-rooted and forms dense floating leaf mats, occurring in waters down to 4m deep.
Diagnostic taxa (% constancy): *Nuphar lutea* (100%). *Nymphaea alba* (down to 3m deep). *Chara globularis* (100%). *Nymphaea alba* (down to 2m deep). *Chara corfuensis* (57.2%).

Distribution: Pamvotida and Lysimachia. Syntaxonomic remarks: Similar to the descriptions in Greece (Papastergiadou 1990; Sarika-Hatzinikolou et al. 2003; Zotos 2006) and Europe (Goldyn et al. 2005; Šumberová 2011a; Lastrucci et al. 2014, 2015; Džigurski et al. 2016; Cvijanović et al. 2018).

**Syntaxon 4.(2).19. Nupharoidetum luteae** (Code NL, Table 3, MNT = 1.2)

Appearance and habitat: Open to closed (>25% cover) floating leaf mats of *Nuphar lutea*, rooting at the lake bottom down to 3m deep.

Diagnostic taxa (% constancy): *Nuphar lutea* (100%).

Distribution: Pamvotida and Lysimachia.

Syntaxonomic remarks: Matches the descriptions of this association (under the name of *Myriophyllo-Nupharetum luteae*) from Greece (Papastergiadou 1990; Sarika-Hatzinikolau et al. 2003) and from throughout Europe (Preising et al. 1990; Solitska-Görnicka and Symonides 2001; Hrůvnák 2002; Melendo et al. 2003; Goldyn et al. 2005; Gabka and Dolata 2010; Šumberová 2011a; Lastrucci et al. 2015; Džigurski et al. 2016; Cvijanović et al. 2018).

**Syntaxon 4.(2).20. Nymphoidetum peltatae** (Code NP, Table 3, MNT = 4.8)

Appearance and habitat: Open to closed (>25% cover) floating leaf mats of *Nymphoides peltata* accompanied by low-abundant lemmids and helophytes. Like all other nymphaeids, *Nymphoides peltata* forms a dense floating leaf canopy, bottom-rooted in shallow waters down to 2m deep, sharing its space with other floating or emerged macrophytes.

Diagnostic taxa (% constancy): *Nymphoides peltata* (100%).

Distribution: Pamvotida and Megali Prespa.

Syntaxonomic remarks: Similar to the descriptions in Greece (Lavrentiades and Pavlidis 1985, co-dominating with *Trapa natans*; Papastergiadou 1990; Sarika-Hatzinikolau et al. 2003) and Europe (Preising et al. 1990; Gabka and Dolata 2010; Šumberová 2011a; Lastrucci et al. 2014; Džigurski et al. 2016; Cvijanović et al. 2018).

**Syntaxon 4.(2).21. Ludwigia peploides community** (Code LP, Table 3, MNT = 2.0)

Appearance and habitat: Open to closed (>25% cover) mats of *Ludwigia peploides* subsp. *montevidensis*, an amphibious perennial macrophyte forming creeping mats on the wet mud and flooded shores of freshwater bodies or floating mats on the muddy surface of the riparian zone. The floating mats, often found within the gaps of *Phragmites australis* reedbeds, reach down to 2m deep, leaving no room for other aquatic macrophytes.

Diagnostic taxa (% constancy): *Ludwigia peploides* ssp. *montevidensis* (100%).

Distribution: Lysimachia.

Syntaxonomic remarks: *Ludwigia peploides* subsp. *montevidensis*, native to South America, is locally naturalized in South Europe, SW Asia and other continents where it is often invasive (Dutartre 1986; Zotos et al. 2006). In South America the association *Polygono-Ludwigietum peploidis* has been described (Padovani et al. 1993; Hauenstein et al. 2002), where *Ludwigia peploides* is often (but not always) accompanied by *Persicaria hydropiperoides* which does not occur in Europe. We did not find *Ludwigia peploides* relevés from Europe other than those published by Zotos (2006) and Zotos et al. (2006), together with *Paspalum distichum* or dominated by *Phragmites australis*. We found *Ludwigia peploides* as the dominant species associated with *Phragmites*. Taking into consideration the ecological similarities between *Ludwigia peploides* and *Ludwigia grandiflora* (Zotos et al. 2006), a diagnostic taxon of the *Nymphaeion*, we assign with some reservations the *Ludwigia peploides* community to that alliance.

**Class 5. Platyhypnidio-Fontinalietea antipyreticae**

**Syntaxon 5.1. Fontinalietum antipyreticae** (Code FA, Table 4, MNT = 4.0)

Appearance and habitat: Patchy carpets dominated by the water moss *Fontinalis antipyretica* usually developing under shady conditions, on rocks in very shallow water (down to 0.5m deep), often in very clear (oligo-mesotrophic) streams, sometimes in lacustrine littoral zones.

Diagnostic taxa (% constancy): *Fontinalis antipyretica* (100%).

Distribution: Kourna and Feneos.

Syntaxonomic remarks: Matches the descriptions from Europe (Dawson and Szoszkiewicz 1999; Fedrotti 2008; Ceschin et al. 2010; Grzybowski et al. 2010). In Greece, only Gradstein and Smittenberg (1977) published a relevé of *Fontinalis antipyretica* together with *Stuckenia pectinata*.

**Class 6. Charaletea intermediae**

**Syntaxon 6.1. Charettum globularis** (Code ChG, Table 4, MNT = 1.4)

Appearance and habitat: Dense (>25% cover) underwater stonewort meadows of *Chara globularis* tolerating a broad range of ecological conditions but thriving in oligo-mesotrophic calcareous freshwater lakes to a depth of 8m.

Diagnostic taxa (% constancy): *Chara globularis* (100%).

Distribution: Feneos.

Syntaxonomic remarks: Matches the descriptions of this association from publications in Europe (Šumberová et al. 2011b; Iakushenko and Borysova 2012; Azzella et al. 2013). In Greece, to our knowledge, no distinct *Chara globularis* community has been hitherto identified.

**Syntaxon 6.2. Magno-Charetum hispidae** (Code CH, Table 4, MNT = 2.1)

Appearance and habitat: Sparse underwater stonewort meadows dominated by *Chara corfuensis* (= *Chara hispida*...
Table 4. Synoptic table of the identified associations and communities belonging to Classes Platyhypnidio-Fontinalietea antipyreticae, Charetea intermediae and Stigeoecionetia tenuis. Taxa constancy in percentage and their average abundance class (r = 0-1%, + = 2-5%, 1 = 6-20%, 2 = 21-40, 3 = 41-60%, 4 = 61-80%, 5 = 81-100%) superscripted are shown. Companion taxa with less than 20% constancy are shown at the end of the Table. Diagnostic taxa for each vegetation type are marked in bold (see relevant text and Table 5 for vegetation type codes).

| Vegetation type code | PA | CHs | CH | CHE | NO | CV | CA | NMu | NHy | CGL | CSGM |
|----------------------|----|-----|----|-----|----|----|----|-----|-----|-----|------|
|                       |    |     |    |     |    |    |    |     |     |     |      |
| PLATYHYPNIDIO-FONTINALIETEA ANTIPYRETICAES |     |     |    |     |    |    |    |     |     |     |      |
| Chareta intermediae | 100 | 71 | 10 | 10 | 10 | 31 | 11 | 11 | 26 | 6  | 83   |
| Nitellopsidetum obtusae | 71 | 10 | 31 | 11 | 11 | 26 | 6  | 83 | 35 |    |      |
| Stigeoecionetia tenuis |    |    |    |    |    |    |    |    |    |    |      |
| Stigeoecionetia tenuis |    |    |    |    |    |    |    |    |    |    |      |

**f. corfensis**, Wood 1962) in oligo-mesotrophic calcareous waters, down to 3m deep.

Diagnostic taxa (% constancy): **Chara corfensis** (100%).

Distribution: Kourna (found also by Langangen 2012).

Syntonymic remarks: Descriptions of this association (often under the name **Chareta hispidae**) from Europe (Preising et al. 1990; Hrivnak et al. 2005; Pelchty and Pukacz 2006; Sumberova et al. 2011b). Pirinen (2011) lumped relevés from lake Vergitori containing Bolboschoenus maritimus and Chara hispida in a complex community.

**Syntaxonomic remarks**: This cluster is a variant of the **Mageno-Charitetum hispidae**.

**Syntaxon 6.4. Nitellopsidetum obtusae** (Code NO, Table 4, MNT = 1.8)

Appearance and habitat: Sparse to dense (25% cover) underwater stonewort meadows dominated by **Nitellopsis obtusa** occurring from oligotrophic to meso-eutrophic calcareous deep standing waters down to 12m deep with muddy deposits.

Diagnostic taxa (% constancy): **Nitellopsis obtusa** (100%).

Distribution: Feneos, Kastoria and Petres.

**Syntaxonomic remarks**: Matches the descriptions in publications of this association scattered in Europe (Solińska-Görnicka and Symonides 2001; Ikushenko and Borysova 2012; Kiprianova 2013). In Greece, a distinct **Nitellopsis obtusa** community has not yet been identified.

**Syntaxon 6.5. Chareta vulgaris** (Code CV, Table 4, MNT = 1.1)

Appearance and habitat: Sparse to dense (>25% cover) underwater stonewort meadows dominated by **Chara vulgaris** in oligo-mesotrophic neutral to slightly alkaline standing fresh water, down to 6m deep.

Diagnostic taxa (% constancy): **Chara vulgaris** (100%).

Distribution: Feneos and Kourna.
### Table 5. Syntaxonomic overview of the plant associations and communities found in the current study.

| Association                          | Syntaxonomic Remarks                                                                 |
|--------------------------------------|--------------------------------------------------------------------------------------|
| Potamion sphaericum                   | Matches the description of this widespread association from Greece (Preising et al. 1990; Goldyn et al. 2005; Hrivnák et al. 2005; Pechenat and Pukacz 2006; Šumberová et al. 2011b; Iakushenko and Borysowa 2012; Kiprianova 2013). |
| Phragmites-Agrostietum verticillati    |                                                                                      |
| Phragmion-Agrostietum verticillati    |                                                                                      |
| Charettium intermediume              | Appearance and habitat: Dense (25%) over underwater stonewort meadows of Chara aspera found in water depths between 3 and 7m, in meso-eutrophic more or less alkaline freshwater. Diagnostic taxa (% constancy): Chara aspera (100%). Distribution: Keran. Syntaxonomic remarks: Matches the description of this widespread association from elsewhere in Europe (Heuff 1984; Preising et al. 1990; Solinska-Gornicka and Symonides 2001; Pechenat and Pukacz 2006; Iakushenko and Borysowa 2012; Azzella et al. 2013; Kiprianova 2013). In Greece, no distinct Chara aspera community has yet been identified. |
| Stigeoclonietum compressi            | Syntaxonomic remarks: Matches the description of this widespread association from Greece (Grigoriadis et al. 2005; Pirini 2011, with Ultericularia vulgaris) and elsewhere in Europe (Preising et al. 1990; Goldyn et al. 2005; Hrivnák et al. 2005; Pelechaty and Pukacz 2006; Šumberová et al. 2011b; Iakushenko and Borysowa 2012; Kiprianova 2013). |
| Charettium asperae                   | Appearance and habitat: Dense (25%) over underwater stonewort meadows of Chara aspera found in water depths between 3 and 7m, in meso-eutrophic more or less alkaline freshwater. Diagnostic taxa (% constancy): Chara aspera (100%). Distribution: Keran. Syntaxonomic remarks: Matches the description of this widespread association from elsewhere in Europe (Heuff 1984; Preising et al. 1990; Solinska-Gornicka and Symonides 2001; Pechenat and Pukacz 2006; Iakushenko and Borysowa 2012; Azzella et al. 2013; Kiprianova 2013). In Greece, no distinct Chara aspera community has yet been identified. |
| Phragmites-Agrostietum verticillati  |                                                                                      |
| Phragmites-Agrostietum verticillati  |                                                                                      |
| Charettium intermediume              |                                                                                      |
| Stigeoclonietum compressi            | Syntaxonomic remarks: Matches the description of this widespread association from Greece (Grigoriadis et al. 2005; Pirini 2011, with Ultericularia vulgaris) and elsewhere in Europe (Preising et al. 1990; Goldyn et al. 2005; Hrivnák et al. 2005; Pelechaty and Pukacz 2006; Šumberová et al. 2011b; Iakushenko and Borysowa 2012; Kiprianova 2013). |
| Phragmites-Agrostietum verticillati  |                                                                                      |
| Phragmites-Agrostietum verticillati  |                                                                                      |
| Charettium intermediume              |                                                                                      |
| Stigeoclonietum compressi            | Syntaxonomic remarks: Matches the description of this widespread association from Greece (Grigoriadis et al. 2005; Pirini 2011, with Ultericularia vulgaris) and elsewhere in Europe (Preising et al. 1990; Goldyn et al. 2005; Hrivnák et al. 2005; Pelechaty and Pukacz 2006; Šumberová et al. 2011b; Iakushenko and Borysowa 2012; Kiprianova 2013). |

### Syntaxon 6.6. Charaetum asperae

| Code | Association                          | Appearance and habitat | Diagnostic taxa | Distribution | Syntaxonomic remarks |
|------|--------------------------------------|------------------------|-----------------|--------------|----------------------|
| CA   | Chara aspera                          | Dense (25%) over stonewort meadows of Chara aspera found in water depths between 3 and 7m, in meso-eutrophic more or less alkaline freshwater. | Chara aspera (100%) | Keran | Matches the description of this widespread association from elsewhere in Europe (Heuff 1984; Preising et al. 1990; Solinska-Gornicka and Symonides 2001; Pechenat and Pukacz 2006; Iakushenko and Borysowa 2012; Azzella et al. 2013; Kiprianova 2013). In Greece, no distinct Chara aspera community has yet been identified. |

### Syntaxon 6.7. Nitelletum mucronatae

| Code | Association                          | Appearance and habitat | Diagnostic taxa | Distribution | Syntaxonomic remarks |
|------|--------------------------------------|------------------------|-----------------|--------------|----------------------|
| NM   | Nitella mucronata                    | Sparse to dense (25%) over underwater stonewort meadows of Nitella mucronata found in very shallow clear oligotrophic alkaline waters, 0–1m deep. | Nitella mucronata (100%) | Keran | Matches the description of this widespread association from Europe (Golub et al. 1991; Landucci et al. 2011; Csiky et al. 2014). In Greece, no community dominated by Nitella mucronata has been identified yet. |
Cladophora glomerata, found in stagnant eutrophic lowland waters. It is a quite light-demanding taxon which is often entangled with other macrophytes (subsequent cluster), or attached to the rocky substrate. These relevés, with a low cover of other aquatic macrophytes, were found in waters down to 5m deep.

Diagnostic taxa (% constancy): *Cladophora glomerata* (100%).

Distribution: Amvrakia, Paralimni, Trichonida, Megali Prespa and Vegoritida.

Syntaxonomic remarks: Matches the descriptions of this association from Europe (Margalef 1949; Den Hartog 1959; Carretero 1986). In Greece, *Cladophoretum glomeratae* has not yet been identified.

Syntaxon 7.2. *Cladophoretum glomeratae*, macrophyte-substratum variant (Code ClGM, Table 4, MNT = 3.3)

Appearance and habitat: This cluster is also assigned to the *Cladophoretum glomeratae* defined by the dominance of the benthic filamentous macroalgae *Cladophora glomerata*, but in this cluster it is accompanied by other aquatic macrophytes, especially *Myriophyllum spicatum* and *Stuckenia pectinata*, serving as the algae's substrate. The relevés within this cluster have been recorded in waters down to 4m deep.

Diagnostic taxa (% constancy): *Cladophora glomerata* (100%), *Myriophyllum spicatum* (82.9%).

Distribution: Kourna, Vegoritida and Petres.

Syntaxonomic remarks: See preceding unit.

Relation of phytosociological units to environmental parameters

Water depth is widely known to be an important environmental parameter which affects the distribution of aquatic plants, by regulating prevailing light conditions, temperature, water chemistry, wave action and substrate granulometry (Spence and Chrystal 1970; Chambers and Kaiff 1985; Middelboe and Markager 1997). Each macrophyte species has its own water depth tolerance limits, which depend on its morphological and physiological characteristics. However, due to the competition for space, light and nutrients from other macrophyte species they are not free to colonize the water volume that falls within their tolerance limits (McCrea 1991; Gopal and Goel 1993; Gross 2003). These mechanisms produce distinct zonation patterns in aquatic vegetation along water depth gradients (Spence 1982; Shipley et al. 1991). Figure 2 summarizes the depth distribution of the 46 described vegetation types, as recorded in the lakes that were surveyed in the current study. Among the helophytic vegetation types (*Plantaginetea majoris*; *Phragmito-Magnocaricetea*) the *Phyla nodiflora* community, and the *Paspalo distichi-Agrostietum verticillatae*, *Scirpetum lacustris*, and *Typhetum angustifoliae* were recorded colonizing the littoral zones to a depth of 1.5m. The *Typhetum domingensis*, *Typhetum latifoliae*, and *Butometum umbellati* were able to reach a bit deeper down to a depth of 2m, while the *Phragmitetum communis* which dominates the littoral zone of Greek lakes, quite often reach-
Figure 3. Distribution of higher-rank syntaxa (classes to alliances) in the lakes of the current study (number of relevés per syntaxon to total number or relevés in each lake). PLA: Plantaginetea majoris; PHR: Phragmito-Magnocaricetea; LEM: Lemnetea; POTA: Potamogetonion; POTB Nymphaeion albae; FON: Platyhypnidio-Fontinalietea antipyreticae; CHA: Charatea intermediae; STI: Stigeclonietae tenuis. Environmental data [TP: Annual mean total phosphorus (μg/L); SD: Secchi depth transparency in meters; EC: Electrical conductivity (μS/cm); WLF: Annual water level fluctuation in meters] are also presented.
es down to a depth of 4m. Freely floating macrophytes (Lemnetea) and anchored floating macrophytes (Nymphaeion albae) are also restricted to shallow waters down to 1m and 3m deep respectively, with the exception of the Ceratophylletum demersi which can be found commonly down to 6m deep. Submerged hydrophytes (Potamogetonion; Charetea intermediae) predominantly colonize the deeper part of the euphotic zone of lacustrine littoral areas, between the zone colonized by emergent vegetation and the aphotic zone. Therefore, the majority of vegetation types belonging to Potamogetonion or Charetea intermediae are usually located in a depth zone starting at 1–2m and reaching 4–6m deep (in Greek waters), depending on the variability of light penetration and the specific lake physico-chemical characteristics. In cases where the euphotic zone reaches more than 6–8m deep, the Potamogetonetum pectinati, Nymphaeion albae, Ceratophylletum demersi, and Charetea intermediae are the most commonly found vegetation types.

An equally important environmental parameter to water depth, that influences the distribution of aquatic plants, is prevailing light conditions. Light penetration in lacustrine ecosystems is highly dependent upon their water quality status (Phillips et al. 1978; Canfield et al. 1985; Middelboe and Markager 1997). Nutrient loading and eutrophication lead to the growth of phytoplankton, epiphytes and filamentous algae, which leads to increased shading and light attenuation. As a result, macrophyte dominance is reduced due to their biomass decline, plant cover reduction and loss of species richness (Phillips et al. 1978; 2016; Sand-Jensen 2000). Figure 3 and Table 6 summarize the relationships we found between the distribution and abundance of higher-rank syntaxa for each lake and the prevailing physico-chemical and hydrological conditions. Positive and significant correlations were found between the distribution of Phragmito-Magnocaricetalia and Nymphaeion albae with total phosphorus concentrations, while Potamogetonion was negatively correlated. In addition, positive and significant correlations were found between Charatea intermediae and Platiphyndio-Fontinalietea antipyreticae with Secchi depth transparency, while Phragmito-Magnocaricetalia was negatively correlated. Only Potamogetonion was positively correlated with electrical conductivity. No syntaxon was correlated significantly with water level fluctuation. Multiple linear regression analysis produced the best solution for the above-mentioned environmental parameters (TP, SD and EC) using the combination of distribution values for five syntaxa: Phragmito-Magnocaricetalia, Potamogetonion, Nymphaeion albae, Charatea intermediae, and Platiphyndio-Fontinalietea. The distribution patterns of these five higher-rank syntaxa appear to act as good indicators of lake eutrophication. Raised total phosphorus concentrations in lake water and lowered water transparency led to the dominance of Phragmito-Magnocaricetalia, and Nymphaeion albae syntaxa in aquatic vegetation. The expansion of Potamogetonion, Charatea intermediae, and Platiphyndio-Fontinalietea syntaxa in aquatic vegetation is associated with lower total phosphorus concentrations and higher values of water transparency.

These results are of relevance for WFD assessment purposes and are similar to those presented in Poikane et al. (2018) that reviewed national macrophyte-based approaches for assessing ecological status according to the WFD. Poikane et al. (2018) reported that a marked decline in submerged vegetation, especially Charophyta (characterizing ‘good’ status according to WFD), and an increase in abundance of floating and emerged plants (characterizing ‘less than good’ status) were the most significant changes along the ecological status gradient. Similar results have also been reported from other areas within Europe, where the indicator value of different groups of taxa belonging to these syntaxa were tested against eutrophication levels in the context of WFD assessment systems (e.g. Penning et al. 2008a, 2008b; Søndergaard et al. 2010; Kolada 2016).

Table 6. Overview of the relationships between the abundance of higher-rank syntaxa (classes to alliances) for each lake within the current study and its environmental variables. Pearson’s correlation coefficient (R) and the p-value of significance are given for each linear regression. Significant relationships (p < 0.05) are marked in bold. The two final rows of the table contain part of the results of the multiple linear regression analysis with the involvement of more than one higher-rank syntaxa (one with all the higher-rank syntaxa and one with those giving the best solution for all the environmental parameters). PLA: Plantaginetea majoris; PHR: Phragmito-Magnocaricetalia; LEM: Lemnetea; POTA: Potamogetonion; POTB Nymphaeion albae; FON: Platiphyndio-Fontinalietea antipyreticae; CHA: Charetea intermediae; STI: Stigeclonietea tenuis; TP: Annual mean total phosphorus (μg/L); SD: Secchi depth transparency in meters; EC: Electrical conductivity (μS/cm); WLF: Annual water level fluctuation in meters.

| Syntaxa in regression | TP | SD | EC | WLF |
|-----------------------|----|----|----|-----|
|                       | R  | p  | R  | p  | R  | p  | R  | p  |
| PHR                   | 0.821 | < 0.001 | -0.585 | 0.011 | -0.444 | 0.065 | -0.296 | 0.233 |
| STI                   | -0.158 | 0.532 | 0.049 | 0.846 | 0.019 | 0.940 | -0.118 | 0.641 |
| LEM                   | -0.221 | 0.379 | -0.321 | 0.194 | -0.299 | 0.228 | -0.131 | 0.604 |
| PLA                   | -0.006 | 0.981 | -0.099 | 0.695 | 0.098 | 0.699 | -0.036 | 0.888 |
| POTA                  | -0.584 | 0.011 | 0.441 | 0.067 | 0.630 | 0.000 | 0.341 | 0.166 |
| POTB                  | 0.594 | 0.009 | -0.282 | 0.258 | -0.235 | 0.348 | -0.078 | 0.759 |
| CHA                   | -0.210 | 0.402 | 0.567 | 0.014 | -0.064 | 0.802 | 0.050 | 0.845 |
| FON                   | -0.187 | 0.458 | 0.545 | 0.019 | 0.347 | 0.560 | 0.040 | 0.876 |
| PHR+STI+LEM+PLA+POTA+POTB+CHA+FON | 0.860 | 0.026 | 0.802 | 0.091 | 0.893 | 0.009 | 0.410 | 0.953 |
| PHR+POTA+POTB+CHA+FON | 0.858 | 0.003 | 0.768 | 0.024 | 0.813 | 0.013 | 0.375 | 0.844 |
Conclusions

The current study is a national-scale phytosociological survey of freshwater lake vegetation, based on the most recent data available (years 2013–2016). Forty-six vegetation types were identified and interpreted for eighteen major Greek freshwater lakes. Among these vegetation types, the following are new records for Greece: Phyla nodiflorum community, Butometum umbellati, Potamogetonemdeno-nodosi, Potamogetonemcompressi, Najadetum minoris, Fontinalieta antipyreticetum, Charetem globularis, Magno-Charetem hispidae, Nettelosidetum obtusae, Charetem asperae, Netteltum mucronatae, Nettelosidetum hyalinae, Cladophoretum glomeratae. A primary analysis on the distribution of higher-rank syntaxa of the 46 vegetation types showed that the majority of these types are significantly affected by physico-chemical parameters indicative of higher levels of eutrophication. Aquatic plant communities could be utilized in eutrophication indices to broaden the assessment of the ecological status of freshwater lakes. Additional research on this topic is needed.

Data availability

The data that support the findings of this study were used under license from The Goulandris Natural History Museum, Greek Biotope/Wetland Centre (EKBY). They are available from the lead author upon reasonable request and with permission of The Goulandris Natural History Museum, Greek Biotope/Wetland Centre (EKBY).

Author contributions

D.Z. and I.T. conceived of the research idea; D.Z. collected vegetation data; V.T. supervised environmental parameters samplings and analyses; D.Z. and I.T. performed statistical analyses; E.B. supervised vegetation type descriptions and syntaxonomical decisions; D.Z., with contributions from I.T. and E.B., wrote the paper; all authors discussed the results and commented on the manuscript.

Acknowledgements

Executed in the frame of the Greek National Water Monitoring Network, according to the JMD 140384/2011, implemented by The Goulandris Natural History Museum, Greek Biotope/Wetland Centre (EKBY). The Network is supervised by the Directorate for the Protection and Management of Water Resources of the Ministry of Environment and Energy. The data used in this report come from Acts MIS 5001204 financed by the European Union Cohesion Fund (Partnership Agreement 2014–2020), MIS 371010, 371138, 371140, 371144, 371145 of the Operational Program "Environment and Sustainable Development" financed by the European Regional Development Fund. Special thanks must be given to G. Poulis, for his contribution to aquatic macrophyte samplings and identification and to E. Tsakiri for the identification of bryophytes. EKBY's personnel conducted monitoring samplings and analysis of environmental parameters.

References

Aguiar FC, Ferreira MT, Albuquerque A, Bernez I (2005) Invasibility patterns of knotgrass (Paspalum distichum) in Portuguese riparian habitats. Weed Technology 19: 509–516. https://doi.org/10.1614/WT-04-080R.1
Azzella MM, Rosati L, Blasi C (2013) Phytosociological survey as a baseline for environmental status assessment: the case of hydropytic vegetation of a deep volcanic lake. Plant Sociology 50: 33–46.
Bergmeier E (2001) Seasonal pools in the vegetation of Gavdos (Greece) – in situ conservation required. Bocconea 13: 511–516.
Biondi E, Bagella S. (2005) Vegetazione e paesaggio vegetale dell’arcipelago di La Maddalena (Sardegna nord-orientale). Fitosociologia 42: 3–99.
Birkinshaw N, Kemp E, Clarke S (2013) The ecology of grass-wrack pondweed Potamogeton compressus. Natural England Commissioned Reports: Number 130.
Braun-Blanquet J (1957) An ordination of upland forest communities of southern Wisconsin. Ecological Monographs 27: 325–349. https://doi.org/10.2307/1942268
Borsukевич L. (2013) The distribution, ecology and phytosociology of rare Potamogeton species in central part of western Ukraine. In: Dygui KH (Ed.) Natural human environment: Dangers, protection, education: Monograph. Oficyna Wydawnicza Wyszzej Szkoły Ekologii i Zarządzania, Warsaw, PL.
Brullo S, Sciacchrello S (2006) La vegetazione del bacino lacustre “Biviere di Gela” (Sicilia meridionale). Fitosociologia 43: 1–20.
Canfield DE, Langeland KA, Linda SB, Haller, WT (1985) Relations between water transparency and maximum depth of macrophyte colonization in lakes. Journal of Aquatic Plant Management 23: 25–28.
Carpenter SR, Lodge DM (1986) Effects of submerged macrophytes on ecosystem processes. Aquatic Botany 26: 341–370. https://doi.org/10.1016/0304-3770(86)90031-8
Carretero JL (1986) Ricefield flora and vegetation in provinces of the Valencia and Tarragona (Spain). Collectanea Botanica 17: 113–124. https://doi.org/10.3989/collectbot.1988.v17.163
CEN – European Committee for Standardization (2007) IS EN 15460 – Water quality – Guidance Standard for the surveying of macrophytes on ecosystem processes. Aquatic Botany 26: 341–370. https://doi.org/10.1016/0304-3770(86)90031-8
Ceschin S, Zucarello V, Caneva G (2010) Role of macrophyte communities as bioindicators of water quality: Application on the Tiber River basin (Italy). Plant Biosystems 144: 528–536. https://doi.org/10.1080/11263500903429221
Chambers PA, Kaiff J (1985) Depth distribution and biomass of submerged aquatic macrophyte communities in relation to Secchi depth. Canadian Journal of Fisheries and Aquatic Sciences 42: 701–709. https://doi.org/10.1139/f85-090
Klosowski S (2006) The relationships between environmental factors and the submerged Potametea associations in lakes of north-eastern Poland. Hydrobiologia 560: 15–29. https://doi.org/10.1007/s10750-005-1141-1

Klosowski S, Jabłońska E (2009) Aquatic and swamp plant communities as indicators of habitat properties of astatic water bodies in north-eastern Poland. Limnologica 39: 115–127. https://doi.org/10.1007/j.1056.2008.01.003

Kolada A (2016) The use of helophytes in assessing eutrophication of temperate lowland lakes: Added value? Aquatic Botany 129: 44–54. https://doi.org/10.1016/j.aquabot.2015.12.002

Kolada A, Hellsten S, Kaminen A, Sondergaard M, Dudley B, Nöges P, Ott I, Ecke F, Mjøle M, … Duel H (2009) Overview and comparison of macrophyte survey methods used in European countries and a proposal of harmonized common sampling protocol to be used for WISER uncertainty exercise including a relevant common species list. Wiser Deliverable D3.2-1. http://www.wiser.eu/results/ delivers/ (accessed 4 Jan 2019)

Kolada A, Willby N, Dudley B, Nöges P, Sondergaard M, Hellsten S, Mjøle M, Penning E, van Geest G, … Karus K (2014) The applicability of macrophyte compositional metrics for assessing eutrophication in European lakes. Ecological Indicators 45: 407–415. https://doi.org/10.1016/j.ecolind.2014.04.049

Kuzmichev AI, Krasnova AN, Kuznetsova LV (2008) The typological structure of hydrophilic flora and vegetation of technologically transformed lakes of Vologda Poozerie. Inland Water Biology 1: 362–370. https://doi.org/10.1134/S1995082908040081

Lance GN, Williams WT (1967) A general theory of classification sorting strategies: I. Hierarchical systems. Computer Journal 9: 373–380. https://doi.org/10.1093/comjnl/9.4.373

Landucci F, Gigante G, Venanzoni R (2011) An application of the Cocktail method for the classification of the hydrophytic vegetation at Lake Trasimeno (Central Italy). Fitosociologia 48: 3–22.

Landucci F, Gigante G, Venanzoni R, Chytrý M (2013) Wetland vegetation of the class Phragmito-Magno-Caricetea in central Italy. Phytocoenologia 43: 67–100. https://doi.org/10.1127/0340-269X/2013/0043-0545

Langangen A (2012) Charophytes (Charales) from Crete (Greece) collected in 2010. Flora Mediterranea 22: 25–32. https://doi.org/10.7320/FIMedit22.025

LaStrucci L, Bonari G, Angiolini C, Casini F, Giallonardo T, Gigante D, Landi M, Landucci F, Venanzoni R, Viciani D (2014) Vegetation of Lakes Chiusi and Montepulciano (Siena, central Italy): updated knowledge and new discoveries. Plant Sociology 51: 29–55.

LaStrucci L, Cerri M, Coppa A, Ferranti F, Ferri V, Foggi B, Lazzaro L, Reale L, Venanzoni R, … Gigante D (2017) Understanding common reed die-back: a phytocoenotic approach to explore the decline of palustrine ecosystems. Plant Sociology 54: 15–28.

LaStrucci L, Valentini E, Dell’Olmo L, Vietina B, Foggi B (2015) Hydrophilous vegetation and habitats of conservation interest in the area of the lake Porta (Tuscany, Central Italy). Atti della Società toscana di scienze naturali Memorie Serie B 122: 131–146.

Lavrentiades G, Pavlidis G (1985) Contribution to research of hydrophytic and helophytic communities of Mikri Prespa. Praktika 4ου Επιστημονικου Συνεδριου Ελληνικός Βοτανικός Ετεριας 1985: 145–155. [in Greek]

Legendre P, Gallagher ED (2001) Ecologically meaningful transformations for ordination of species data. Oecologia 129: 271–280. https://doi.org/10.1007/s004420100716

Kłosowski S, Stokowski A, Mileta M, Pashiardis S, Hjeklik L, … Petrovic P (2002) Dai study for the species data. Oecologia 129: 271–280. https://doi.org/10.1007/s004420100716
Vegetation Classification and Survey

Lukács BA, Dévai G, Tóthméresz B (2009) Aquatic macrophytes as bioindicators of water chemistry in nutrient rich backwaters along the Upper-Tisza river (in Hungarian). Phytoecoenologia 39: 287–293. https://doi.org/10.1117/0240-269X/2009/0099-0287

Maechler M, Rousseuw P, Struyf A, Hubert M, Hornik K (2018) cluster: Cluster Analysis Basics and Extensions. R package version 2.0-7.1. https://CRAN.R-project.org/package=cluster

Margalef R (1949). Las asociaciones de algas en las aguas dulces del Noreste de España. Vegetatio 1: 258–284. https://doi.org/10.1007/BF00184535

Mavromati E, Kagalou I, Kemitzoglou D, Apostolakis A, Tsiaoussi V (2017) Linkages between physicochemical status and hydromorphology in Greek lakes under WFD policy. European Water 58: 273–279.

McCreary NJ (1991) Competition as a mechanism of submersed macrophyte community structure. Aquatic Botany 41: 177–193. https://doi.org/10.1016/0304-3770(91)90043-5

Middelboe AL, Markager S (1997) Depth limits and minimum light requirements of freshwater macrophytes. Freshwater Biology 37: 553–568. https://doi.org/10.1046/j.1365-2427.1997.00183.x

Melendo M, Cane E, Válle F (2003) Synopsis of plant communities of the class Potametea in the southern Iberian Peninsula. Acta Botanica Gallica 150: 429–444. https://doi.org/10.1080/12538078.2003.10516611

Mucina L, Bůňkůn H, Dierssen K, Theurillat JP, Raus T, Čarní A, Šumberová K, Willner W, Dengler J, ... Tichý L (2016) Vegetation of Europe: hierarchical floristic classification system of vascular plant, bryophyte, lichen and algal communities. Applied Vegetation Science 19: 3–264. https://doi.org/10.1111/avsc.12257

Nagy J, Gál B, Tuba Z, Szederhelyi T, Csóbel, S, Szirmai O, Cserhalmi D, Úrmos Z (2009) Monodominant plant associations in the Bodrogköz (NE Hungary) new for science and for Hungary. Thaiszia – Journal of Botany 19: 299–314.

Ninot JM, Font X, Masalles RM, Vigo J (2011) Syntaxonomic consecutions of the vegetation of Catalonia and Andorra. II: Ruderal communities. Acta Botanica Barcinonensis 53: 113–189.

Oksanen J (1999) Modern multidimensional scaling. Pages 176–195 in: Michael Greenacre and Jari Oksanen (eds.) Recent advances in multidimensional data analysis. Chapman & Hall, London.

Penning WE, Mjelde M, Dudley B, Hellsten S, Hanganus J, Kolada A, van den Berg M, Poikane S, Phillips G, ... Ecke F (2008a) Using aquatic macrophyte community indices to define the ecological status of European lakes. Aquatic Ecology 42: 253–264. https://doi.org/10.1007/s10452-008-9183-x

Penning WE, Mjelde M, Dudley B, Hellsten S, Hanganus J, Kolada A, van den Berg M, Poikane S, Phillips G, ... Ecke F (2008b) Classifying aquatic macrophytes as indicators of eutrophication in European lakes. Aquatic Ecology 42: 237–251. https://doi.org/10.1007/s10452-008-9182-y

Phillips GL, Eminson D, Moss B (1978) A mechanism to account for macrophyte decline in progressively eutrophicated freshwaters. Aquatic Botany 4: 103–126. https://doi.org/10.1016/0304-3770(78)90012-8

Phillips GL, Willby N, Moss B (2016) Submerged macrophyte decline in shallow lakes: what have we learned in the last forty years? Aquatic Botany 135: 37–45. https://doi.org/10.1016/j.aquabot.2016.04.004

Pirini BC (2011) The ecosystem of Lakes Vegoritida and Petron: flora, vegetation and plant geography. PhD Thesis, Aristotle University of Thessaloniki, GR. [in Greek]

Poikane S, Portielje R, Denys L, Eifferts D, Kelly M, Kolada A, Mæmets H, Phillips G, Sondergaard M, ... van den Berg MS (2018) Macrophyte assessment in European lakes: Diverse approaches but convergent views of ‘good’ ecological status. Ecological Indicators 94: 185–197. https://doi.org/10.1016/j.ecolind.2018.06.056

Preising E, Vahle –, Brandes D, Hofmeister H, Tüxen J, Weber HE (1990) Die Pflanzengesellschaften Niedersachsens. Bestandsentwicklung, Gefährdung und Schutzprobleme. Wasser- und Sumpfplanzenge sellschaften des Südwesteuropa. Naturschutz und Landschaftspflege in Niedersachsen 20: 47–161.

R Core Team (2018) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Sala OE, Chapin III FS, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, ... Soule ME (1997) Global biodiversity scenarios for the year 2100. Science 278: 1770–1774. https://doi.org/10.1126/science.287.5459.1770

Sand-Jensen K, Rius T, Vestergaard O, Larsen SE (2000) Macrophyte decline in Danish lakes and streams over the past 100 years. Journal of Ecology 88: 1030–1040. https://doi.org/10.1046/j.1365-2745.2000.00519.x

Sarma M, Dimopoulos P, Yannitsaros A (2005) Contribution to the knowledge of the wetland flora and vegetation of Avmrakios Gulf, W Greece. Willdenowia 35: 69–85. https://doi.org/10.3372/wi.35.35105

Sarka-Hatzinikolaou M, Yannitsaros A, Babalonas D (2003) The macrophytic vegetation of seven aquatic ecosystems of Epirus (NW Greece). Phytocoenologia 33: 93–151. https://doi.org/10.1117/0240-269X/2003/0033-0093

Sharma RA, Singh R (2013) A review on Phyla nodiflora Linn.: A wild wetland medicinal herb. International Journal of Pharmaceutical Sciences Review and Research 20: 57–63.

Shipley B, Keddy PA, Lefkovitch LP (1991) Mechanisms producing plant species richness on the Galapagos Islands. Ecology 72: 1420–1424. https://doi.org/10.2307/1940291

Søndergaard M, Johansson LS, Lauridsen TL, Jorgensen TB, Liboriussen L, Jeppesen E (2010) Submerged macrophytes as indicators of eutrophication in European lakes. Aquatic Ecology 42: 253–264. https://doi.org/10.1007/s10452-008-9183-x

Søndergaard M, Johansson LS, Lauridsen TL, Jorgensen TB, Liboriussen L, Jeppesen E (2010) Submerged macrophytes as indicators of the
ecological quality of lakes. Freshwater Biology 55: 893–908. https://doi.org/10.1111/j.1365-2427.2009.02331.x

Spence DHN (1982) The zonation of plants in freshwater lakes. Advances in Ecological Research 12: 37–125. https://doi.org/10.1016/S0065-2504(08)60077-X

Spence DHN, Chrystal J (1970) Photosynthesis and zonation of freshwater macrophytes. I. Depth distribution and shade tolerance. New Phytologist 69: 205–215. https://doi.org/10.1111/j.1469-8137.1970.tb04064.x

Stępień E, Zawal A, Buczyńska P, Buczyńska E (2015) Changes in the vegetation of a small lowland river valley (Krapiel, NW Poland) after dredging. Acta Biologica 22: 167–196. https://doi.org/10.18276/ab.2015.22-13

Šumberová K (2011a) Vegetace vodních rostlin zakořeněných ve dně (Potametea). Vegetation of aquatic plants rooted in the bottom. In: Chytrý M (Ed.) Vegetace České republiky, 3, Vodní a mokřadní vegetace. Vegetation of the Czech Republic, 3, Aquatic and wetland vegetation. Academia, Prague, CZ, 100–247.

Šumberová K (2011b) Vegetace volně plovoucích vodních rostlin (Lemnetea). Vegetation of free floating aquatic plants. In: Chytrý M (Ed.) Vegetace České republiky, 3, Vodní a mokřadní vegetace. Vegetation of the Czech Republic, 3, Aquatic and wetland vegetation. Academia, Prague, CZ, 43–99.

Šumberová K, Hájková P, Chytrý M, Hroudová Z, Sádo J, Hájek M, Hrivnák R, Navrátilová J, Hanáková P, Ektrová E (2011a) Vegetace rákosin a vysokých ostřic (Phragmito-Magno-Caricea). Marsh vegetation. In: Chytrý M (Ed.) Vegetace České republiky, 3, Vodní a mokřadní vegetace. Vegetation of the Czech Republic, 3, Aquatic and wetland vegetation. Academia, Prague, CZ, 385–579.

Šumberová K, Hrivnák R, Rydl J, Ofaheľová H (2011b) Vegetace parožnatek (Charetea). Vegetation of stoneworts. In: Chytrý M (Ed.) Vegetace České republiky, 3, Vodní a mokřadní vegetace. Vegetation of the Czech Republic, 3, Aquatic and wetland vegetation. Academia, Prague, CZ, 248–267.

Täuscher L, van de Weyer K (2015) Die Armleuchteralgen-Gesellschaften Deutschlands. In: Arbeitsgruppe Characeen Deutschlands (Ed.) Armleuchteralgen. Die Characeen Deutschlands. Springer Spektrum, Berlin, Heidelberg, DE, 139–147. https://doi.org/10.1007/978-3-662-47797-7_9

Wickam H, (2017) tidyverse: Easily install and load the ’Tidyverse’. R package version 1.2.1. https://CRAN.R-project.org/package=tidyverse.

Wood RD (1962) New combinations and taxa in the revision of Characeae. Taxon 11: 7–25. https://doi.org/10.2307/1216853

Zotas A, Sarika M, Lucas E, Dimopoulos P (2006) Ludwigia peploides subsp. montevidensis, a new alien taxon for the flora of Greece and the Balkans. Journal of Biological Research 5: 71–78.

E-mail and ORCID

Dimitrios Zervas (Corresponding author, dzervas@ekby.gr), ORCID: https://orcid.org/0000-0002-2892-6046

Ioannis Tsiripidis (tsiripid@bio.auth.gr)

Erwin Bergmeier (erwin.bergmeier@bio.uni-goettingen.de)

Vasiliki Tsiaoussi (vasso@ekby.gr)

Supplementary material

Supplementary material 1
Bibliographic data sources of Greek aquatic plant communities.
Link: https://10.3897/VCS/2020/48377.suppl1

Supplementary material 2
Summary of the recorded taxa in the studied lakes.
Link: https://doi.org/10.3897/VCS/2020/48377.suppl2

Supplementary material 3
Resulting graphs of cluster statistics.
Link: https://doi.org/10.3897/VCS/2020/48377.suppl3

Supplementary material 4
Classification dendrogram of the current study.
Link: https://doi.org/10.3897/VCS/2020/48377.suppl4
Supplementary material 5
Selected taxa combinations of diagnostic taxa.
Link: https://doi.org/10.3897/VCS/2020/48377.suppl5

Supplementary material 6
Distribution of the recorded vegetation types.
Link: https://doi.org/10.3897/VCS/2020/48377.suppl6