# Vegetation ecology of Kalodiki Fen (NW Greece)

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**Abstract:** Freshwater wetlands around the Mediterranean Sea have decreased considerably in number and quality. Greece has lost two thirds of its wetlands during the last seventy-five years; however, many wetlands with considerable conservation value remained. Kalodiki Fen is an inland, freshwater wetland belonging to the western chain of Greek wetlands. This paper describes the plant communities of Kalodiki Fen and their synecology. To determine the relationship between vegetation and environmental parameters, the vegetation of Kalodiki Fen is described and analysed in terms of parameters determining the observed distribution pattern. Eighteen vegetation types, of which nine are ranked as associations and nine as frame communities, are described and are presented in a synoptic table. They belong to the *Phragmition communis, Magnocaricion elatae, Nymphaeion albae, Parvopotamion, Ranunculion aquatilis, Lolio-Potentillion anserinae, Nerion oleandri,* and *Bidention tripartitae.* Through ordination, soil moisture and water depth, and to a lesser extent nitrogen, were identified as underlying environmental factors determining the composition of these plant communities. Community differentiation follows an edaphic-water depth pattern. The floristic and vegetation value of the wetland is discussed as a basis for the application of conservation management measures.

**Key words:** aquatic vegetation, classification, ordination, community ecology, hydrology, nature conservation.

## Introduction

Seventy-five years ago, Greece had three times as many wetlands as it has today. Many of these wetlands were drained as they were considered sources of malaria in the past, and the surface area of most of the remaining lakes has decreased. After 1920, a rapid increase in wetland loss was observed. Yet complete drainage is not the only threat; unwise and unsustainable use of the wetlands also causes much damage (Gerakis, 1992). In spite of past heavy losses, Greece still has many wetlands of national and international importance. The remaining wetlands presently cover over 200,000 ha and number about 400, including fifty-six lakes covering a total of 59,767 ha (Gerakis & Koutrakis, 1996). Ecological data on many Greek wetlands are still very limited, especially data on their vegetation ecology.

Kalodiki is an inland freshwater fen selected as one of the 236 proposed Sites of Community Interest (pSCI), for incorporation into the Natura 2000 network of Greece. Taking into consideration also the Special Protection Areas of Greece (SPA), the total number of the Natura 2000 sites is 359 at present, since 31 sites are simultaneously pSCI and SPAs (Dafis et al., 1996, unpubl. data). It is one of the thirty-nine Greek wetland sites assigned to the wetland type "freshwater marshes and meadows" which covers a total area of 45,745 ha (Verhoeven, 1992b). Moreover, Kalodiki with an area of 1650 ha, is one of the 196 Greek Important Bird Areas (IBA's), covering a total 34,332 km$^2$, ca 26% of the surface area of Greece (Heath et al., 2000). Kalodiki Fen meets the criteria documenting the international importance of the site for *Aythya myroca* (ferruginous duck) at a European level. Exploitation of underground water for consumption and irrigation purposes, surface water pumping, cultivation of the surrounding area are the present threats of primary relevance affecting the flora and vegetation of Kalodiki Fen.

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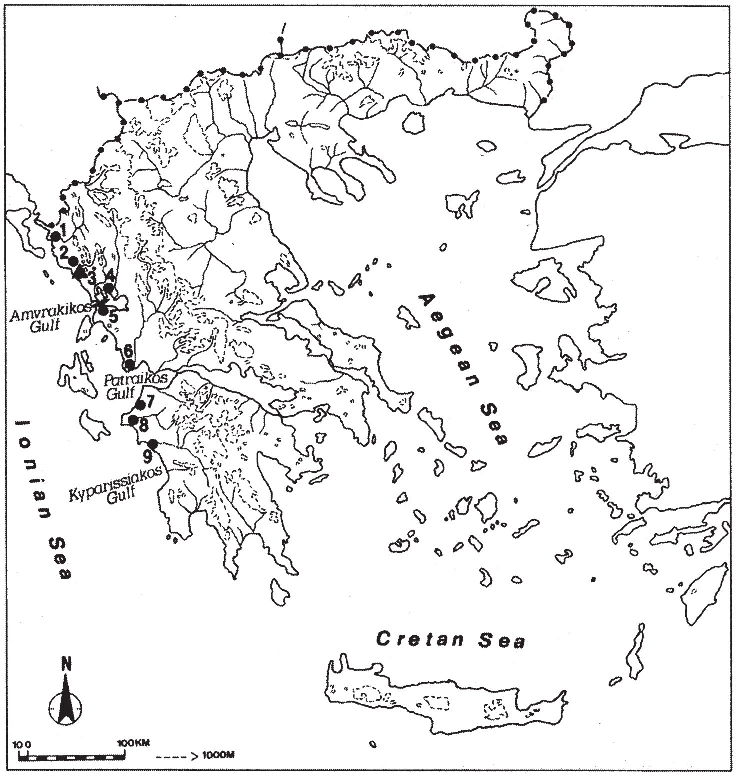


Fig. 1. Map of Greece. The position of Kalodiki and the most important wetlands of Western Greece are indicated. 1: Kalamas Delta; 2: Kalodiki Fen; 3: Acheron Delta; 4: Louros-Arachtos Delta and Amvrakikos Gulf; 5: Lakes Vulkaria and Saltini; 6: Acheloos Delta, Lagoon Messolongi-Aitolikon and estuaries of River Evros; 7: Strofilia coastal area; 8: Pineios Delta; 9: Alfeios Delta.

Kalodiki Fen belongs to the western chain of Greek wetlands situated along the coast of the Ionian Sea. This chain includes extensive deltas and lagoons in Kyparissiakos, Patraikos and Amvrakikos Gulfs, the Akarnanian lakes and marshes, and the lakes of Epiros (Fig. 1). Kalodiki Fen is of ecological interest because of its wildlife, especially the bird fauna, water quality (KOURTELI & ECONOMOU, 1992), interesting flora, well-developed aquatic vegetation (SARIKA-HATZINIKOLAOU, 1999; SARIKA-HATZINIKOLAOU et al., 1993a,b, 1996, 2003) and landscape value.

This paper aims at: a) performing a detailed vegetation survey by means of phytosociological and gradient analytical methods, b) relating and the results with the hydrology of Kalodiki wetland, c) providing a plant-ecological interpretation of the established communities, and d) providing the necessary ecological basis for the conservation management of Kalodiki Fen.

## Study area

Kalodiki Fen is located in W Epiros, NW Greece (Fig. 1) and it extends between 20°26′46″E and 20°28′14″E and 39°19′20″N and 39°17′53″N. Kalodiki wetland consists of one large and one small lake embedded in a topogenous mire or fen, located in a small basin representing a tectonic depression. The fen consists of two peat lands very close to each other occupying together an area of 195 ha surrounded by hills of 550 m altitude.

During the Late Glacial period, a freshwater lake supplied mainly by karstic water occupied the greatest part of the basin. Since the beginning of the Holocene epoch, peat accumulated gradually, and consequently the SSE of the basin converted into a fen. In 1992, the average peat formation was 3.5m and 0.5m thick in the largest and smallest fen, respectively. Since the Late Pleistocene, the sea has not influenced Kalodiki Fen and since 11,000 B.C. it has often been flooded by surface freshwaters. Today, inorganic material carried by brooks and rivulets also flows into the basin forming alluvial fans. The water level of Kalodiki wetland fluctuates seasonally and is highest during winter. More specifically, SARIKA-HATZINIKOLAOU et al. (1993a) recorded a water level fluctuation of 0–5 m. In Greece, 1987–1994 were very dry years resulting in a low water level and, according to BOTIS et al. (1993), in the autumn of 1992 Kalodiki Fen dried out completely; surface water was absent and the groundwater table dropped to 1.5–2.5 m below the soil surface. After reflooding, the freshwater, aquatic plant communities proved to be very resilient. The fresh alkaline water is very clear, has a low hardness value (144–205 mg/L $CaCO_3$) and is rich in phosphorus, nitrogen and iron. Based on these data, GEORGIADIS (1994) concluded that the fen is not influenced by pollution.

## Material and methods

*Recording relevés and species identification*

During May and June 1996, 299 relevés were made according to the Braun-Blanquet method (KENT & COKER, 1992; WESTHOFF & VAN DER MAAREL, 1973). In plots of 6 $m^2$ cover-abundance was estimated using the extended (9-point) Braun-Blanquet scale (BARKMAN et al., 1964). Plant species were sampled using a rake in order to explore the whole volume of each relevé. Taxa nomenclature in this paper follows STRID & TAN (1997, 2002) and TUTIN et al. (1968–1993).

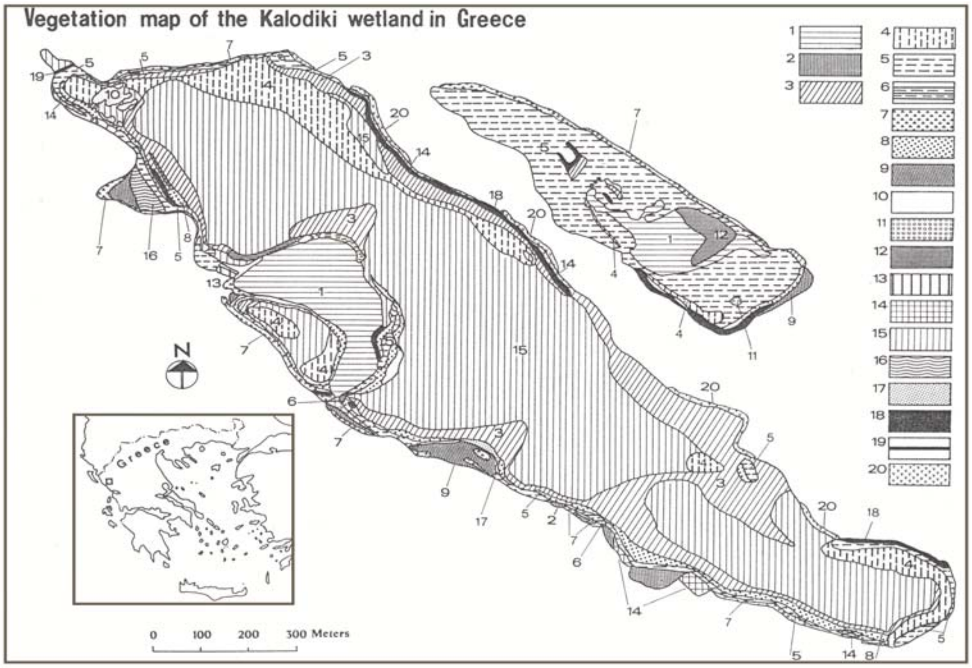


Fig. 2. Vegetation map of Kalodiki Fen. The codes for the vegetation mapping units (1–20) included in the legend are in correspondence with the described plant communities, except for 1: non-cultivated land and abandoned fields, and 5: water.

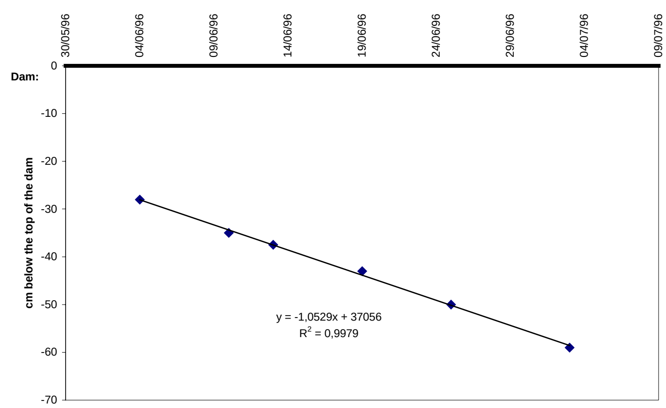


Fig. 3. Change in the water level of Kalodiki Fen during the summer season of 1996.

For phytosociological identification and syntaxonomic assignment of the plant communities we used Horvat et al. (1974), Oberdorfer (1990), Pott (1992), Schaminée et al. (1995), Schubert et al. (1995), Rodwell et al. (1995) and Rodwell et al. (2002). Apart from saturated communities (associations), unsaturated, so-called frame communities, were distinguished using the deductive method (Kopecký, 1978; Kopecký & Hejný, 1978). A plant community is considered phytosociologically saturated if it can be assigned to the association level, because sufficient numbers of characteristic species of that level are present. With increasing disturbance, and occasionally natural dynamics, character species of lower classification levels disappear and plant communities can only be assigned at the level of alliance, order or class. The differential species mentioned in this overview of plant communities are not differential in a syntaxonomic sense; they differentiate the communities as found in the Kalodiki wetland.

The vegetation map (Fig. 2) was drawn by estimating the distances between borders while rowing through the wetland and by using the GPS coordinates of the relevés. The distances between the borders of the inaccessible plant communities in the centre of the fen were estimated.

*Environmental factors*

Water depth was measured in each relevé. As the water level dropped gradually, later measurements had to be adjusted to one date, i.e. the beginning of May. For this reason, the lowering of the water level was measured regularly during the research period (Fig. 3).

In June 1996, water samples were taken and tested for electric conductivity and pH. For this sampling, five relevés were selected per plant community by means of a DCA ordination plot (Hill, 1979b). The even distribution of the selected relevés, from one cluster, over the ordination diagram was used as a criterion for the selection of these relevés.

For each relevé, weighted mean Ellenberg indicator values (Ellenberg et al., 1992) were calculated for moisture and nitrogen. The average values were weighed by the ordinal cover-abundance values (van der Maarel, 1979).

*Data analysis*

The relevés were classified by means of TWINSPAN (Hill, 1979a). A few relevés were reshuffled by hand in order to obtain more homogenous clusters. The final full table has been summarized into a synoptic table, indicating constancy class and characteristic cover. Characteristic cover means the average of the cover values of a species within a cluster excluding zero presence. Species with comparable syntaxonomic status were grouped into syntaxonomic species groups. The same species present in differential, as well as in constant species groups are marked by an asterisk (*) and given once.

Ordination analyses were carried out using the CANOCO package (ter Braak & Šmilauer, 1998). Water-depth, pH, and Ellenberg figures were related to the first two axes of an indirect (DCA) ordination on separate relevés and on cluster centroids. A direct (CCA) ordination was also performed on the cluster centroids (Fig. 6). The coefficients

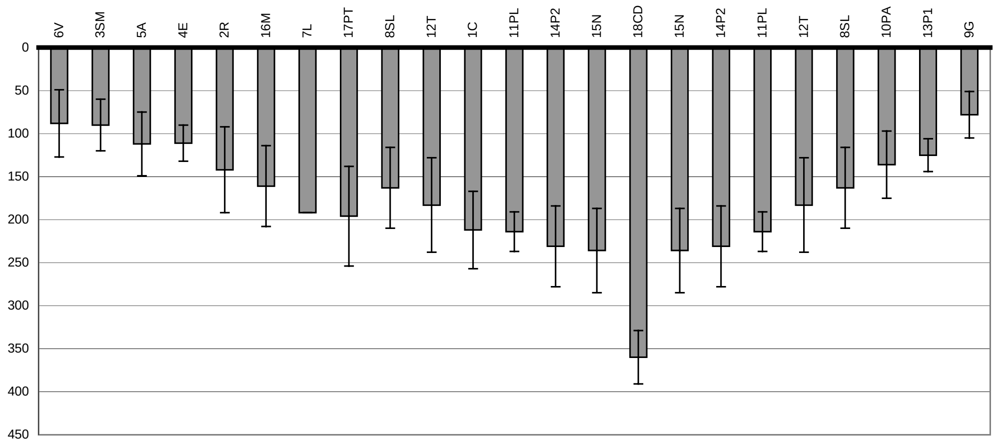


Fig. 4. Mean water depth (cm) in the different plant communities during May, as extrapolated using Figure 3. The standard deviation is indicated. For an explanation of the plant community codes see Table 1. The plant communities are sorted by their presence in Kalodiki fen, from the west side to the east side.

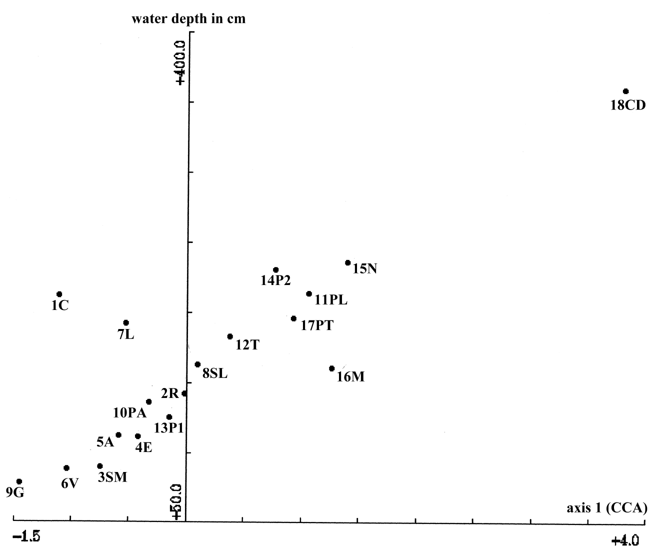


Fig. 5. Relation between the order of plant communities along the first axis of a CCA analysis with water depth. The plant community codes are given in Table 1.

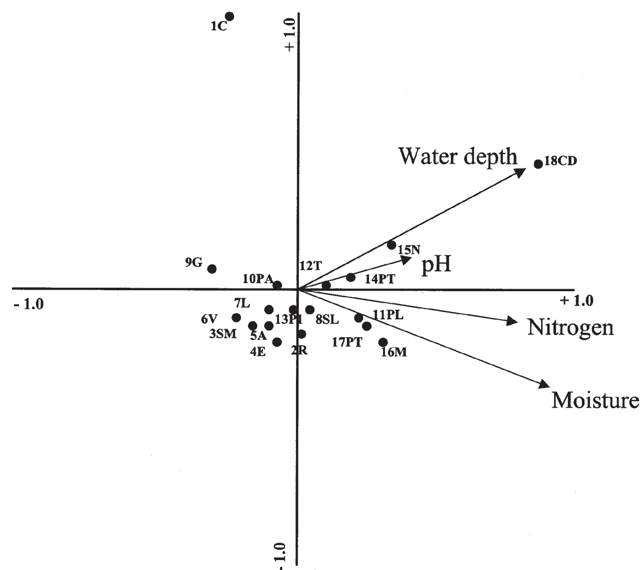


Fig. 6. CCA ordination diagram of the cluster centroids of the plant communities distinguished in Kalodiki Fen and environmental variables. Arrows indicate the relation between water depth, nitrogen, moisture, pH and the ordination axes. The plant community codes are given in Table 1.

of determination ($r^2$) were calculated and are presented in the results. A Monte Carlo permutation test was performed to investigate the statistical significance of the effects of the impact variable.

## Results and discussion

*Vegetation types*

Eighteen plant communities within the fourth level of division were selected for interpretation in the TWINSPAN classification of the Kalodiki vegetation data. The syntaxonomic assignment of these plant communities is given in Table 1. In the synoptic table (Tab. 2), the species composition of each plant community is summarized. In each column, representing one plant community, the frequency and mean ordinal cover-abundance value are given. A description of the floristic structure, ecology and syntaxonomy of the plant communities is given below. The vegetation map (Fig. 2) shows the distribution pattern of the described plant communities. The description of the distinguished vegetation types follows their assignment into high-rank syntaxa.

### I) *Phragmito-Magnocaricetea*

In Kalodiki Fen five associations and one fragmentary or coenologically unsaturated, so-called "frame community", represent the *Phragmito-Magnocaricetea.*

### Frame community of *Phalaris arundinacea* – [*Phragmito-Magnocaricetea*] (Cluster 10PA, Tab. 2, Vegetation mapping unit: 20)

**Syntaxonomy:** This cluster of relevés has been assigned to the frame community due to the dominance

Table 1. Syntaxonomic overview of the plant communities in Kalodiki wetland and their nutrient availability.

***Phragmito-Magnocaricetea* Klika in Klika et Novák 1941**
***Phragmitetalia* Koch 1926**
**Frame community of *Phalaris arundinacea* – [*Phragmitetalia*]
***Phragmition communis* Koch 1926**
***Scirpetum lacustris* Chouard 1924
**Alismo-Scirpetum maritimi* (Tx. 1937) Schaminée, Van 't Veer et Weeda 1995
*subass. *inops* Schaminée, Van 't Veer et Weeda 1995
** *Typho-Phragmitetum* (Koch 1926) Schaminée, Van 't Veer et Weeda 1995
***typhetosum angustifoliae* Schaminée, Van 't Veer et Weeda 1995
**subass. *typicum* Schaminée, Van 't Veer et Weeda 1995
**Eleocharitetum palustris* Schennikow 1919
***Magnocaricion elatae* Koch 1926**
**Caricetum gracilis* Almquist 1929

***Potametea* Klika in Klika et Novak 1941**
**Frame community of *Myriophyllum spicatum* – [*Potametea*]
***Potametalia* Koch 1926 em. Schaminée et al. 1990**
***Frame community of *Ceratophyllum demersum* – [*Nupharo-Potametalia*]
***Nymphaeion albae* Oberd. 1957**
***Potametum lucentis* Hueck 1931
***Myriophyllo-Nupharetum* Koch ex Hueck 1931
***Parvopotamion* (Vollmar 1947) Den Hartog et Segal 1964**
*Frame community of *Potamogeton trichoides* [*Parvopotamion*]
***Ranunculion aquatilis* Passarge 1964**
**Ranunculetum aquatilis* Sauer 1947
**Transitional unit between *Typho-Phragmitetum, Potametum lucentis* and *Myriophyllo-Nupharetum*

***Molinio-Arrhenatheretea* Tx. 1937**
***Potentillo-Polygonetalia* Tx. 1947**
***Lolio – Potentillion anserinae*** Tx. 1947
*Frame community of *Agrostis stolonifera* [*Lolio-Potentillion anserinae*]
*Community of *Gratiola officinalis* (*Lolio-Potentillion anserinae/Magnocaricion elatea*)

***Nerio-Tamaricetea* Br.-bl. et O. Bolòs 1958**
***Tamaricetalia africanae* Br.-bl. et O. Bolòs 1958**
***Nerion oleandri* Eig 1946**
* *Vitex agnus-castus* scrub of the community *Nerium-Tamarix tetranda*

***Bidentetea tripartiti* Tx. et al. ex von Rochow 1951**
***Bidentetalia tripartitae* Br.-bl. et Tx. ex Klika et Hadač 1944**
***Bidention tripartitae* Nordhagen 1940**
*Community of *Ludwigia palustris*

*: Nutrient availability ranging from slightly less than intermediate, to intermediate (Ellenberg values 4–5), **: Nutrient availability ranging from intermediate to rather high (Ellenberg values 5–6), ***: Nutrient availability ranging from high to extremely high (Ellenberg value 8).

of *Phalaris arundinacea* (Weeda et al., 1995), which is very frequently in combination with the constant taxa *Ludwigia palustris* and *Utricularia australis.* The distribution of this community within Kalodiki Fen is very limited and a bordering garbage dump influences the species composition.

**Differential species: ****Phalaris arundinacea* (dominant).

**Constant species:** *Ludwigia palustris*, *Utricularia australis.*

**Ecology:** The frame community of *Phalaris arundinacea* occurs in nitrate and phosphate rich waters on mineral or organic soils with a strongly fluctuating water level, which can drop to 0.5–1 m below ground surface in summer. It also grows on peat soils after drainage (Weeda et al., 1995). According to Pott (1992), prolonged inundation is avoided. Dominance of *P. arundinacea* is often an indication of human disturbances such as drainage or eutrophication.

### Ia) *Phragmition communis*

#### *Scirpetum lacustris* (Cluster 8SL, Tab. 2, Vegetation mapping unit: 19)

**Syntaxonomy:** The *Scirpetum lacustris* (8SL) is represented by the typical subassociation, which is characterized by the dominant species *Schoenoplectus lacustris* subsp. *lacustris* and the presence of the following diagnostic hydrophytic species: *Nymphaea alba, Utricularia australis* and *Potamogeton lucens.*

**Differential species: ****Schoenoplectus lacustris* (dominant).

**Constant species:** *Agrostis stolonifera, Utricularia australis.*

**Ecology:** This community is known from open, nutrient rich waters of fens, canals, and other relatively extensive water bodies. *Scirpus lacustris* grows in water with depths up to 3 or 3.5 m (Weeda et al., 1995)

Table 2. Synoptic table of Kalodiki Fen vegetation.

| **Cluster:** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **11** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Code of plant communities** | **C** | **R** | **SM** | **E** | **A** | **V** | **L** | **SL** | **G** | **PA** | **PL** | **T** | **P1** | **P2** | **N** | **M** | **PT** | **CD** |
| Number of relevés: | 20 | 21 | 11 | 16 | 27 | 20 | 1 | 23 | 20 | 8 | 20 | 21 | 4 | 16 | 20 | 10 | 21 | 20 |
| Mean number of species: | 4.8 | 7.2 | 7.4 | 5.9 | 4.9 | 7.6 | 3.0 | 6.1 | 6.7 | 6.3 | 5.4 | 5.8 | 5.0 | 8.0 | 5.1 | 6.6 | 6.0 | 1.3 |
| Standard deviation: | 1.5 | 2.1 | 1.7 | 1.5 | 1.9 | 3.0 | 0.0 | 1.8 | 1.2 | 2.0 | 1.5 | 2.0 | 0.7 | 1.1 | 1.9 | 2.3 | 2.2 | 0.6 |
| ***PHRAGMITO-MAGNOCARICETEA*** | | | | | | | | | | | | | | | | | | |
| *Phragmites australis* | – | $2^2$ | – | – | – | – | – | – | $+^1$ | $+^3$ | – | – | $+^2$ | $5^8$ | $5^5$ | – | – | – |
| *Sium latifolium* | – | – | $+^1$ | – | – | $+^1$ | $2^1$ | – | – | – | $1^1$ | – | – | – | – | – | $1^1$ | $1^2$ |
| *Sparganium erectum* s. *erectum* | – | – | – | – | – | – | – | – | – | – | – | $+^1$ | – | – | – | – | – | – |
| *Lycopus europaeus* | $+^2$ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Myosotis palustris* agg. | – | – | – | – | – | – | – | $2^2$ | – | – | – | $+^3$ | – | – | – | – | – | – |
| *Phalaris arundinacea* | – | – | – | – | – | – | – | – | – | $5^9$ | – | $+^5$ | – | – | – | – | – | – |
| *Oenanthe fistulosa* | – | $+^1$ | $3^2$ | – | $+^2$ | $+^2$ | – | $1^2$ | – | – | – | – | – | – | – | – | – | – |
| *Eleocharis pal.* s. *palustris* | – | $3^3$ | $3^3$ | $5^7$ | $3^4$ | $2^2$ | – | – | – | $1^3$ | $+^2$ | – | – | – | – | – | – | – |
| *Baldellia ranunculoides* | – | $2^2$ | $2^1$ | $1^1$ | $1^2$ | $2^2$ | – | $2^2$ | $4^3$ | $1^2$ | – | $1^3$ | – | – | $+^1$ | $1^2$ | $2^2$ | – |
| *Berula erecta* | – | – | – | – | – | $+^1$ | – | – | – | – | – | – | – | – | – | – | – | – |
| *Lythrum salicaria* | $2^2$ | – | – | – | – | $+^1$ | – | – | – | – | – | $+^1$ | – | – | – | – | – | – |
| ***Phragmitetalia*** | | | | | | | | | | | | | | | | | | |
| *Typha angustifolia* | $+^2$ | – | – | – | – | – | – | $2^3$ | – | $2^2$ | – | $5^8$ | $2^2$ | $5^3$ | $+^1$ | – | – | – |
| ***Phragmition communis*** | | | | | | | | | | | | | | | | | | |
| *Schoenoplectus lacustris* s.*lacustris* | – | – | – | – | $+^3$ | – | – | $5^8$ | $2^2$ | – | – | $1^2$ | $2^2$ | – | – | – | – | – |
| *Bolboschoenus maritimus* | – | $1^1$ | $5^7$ | – | $2^2$ | $2^2$ | – | – | $1^3$ | – | – | – | – | – | – | – | – | – |
| *Mentha aquatica* | $1^2$ | – | – | – | $1^3$ | $2^3$ | – | $+^2$ | – | $1^2$ | – | $+^2$ | – | $1^1$ | $+^1$ | – | $+^2$ | – |
| ***Magnocaricion elatae*** | | | | | | | | | | | | | | | | | | |
| *Carex acuta* | $5^9$ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Lysimachia vulgaris* | $4^2$ | $1^2$ | – | – | $+^2$ | $+^1$ | – | – | – | – | – | – | $2^1$ | – | – | – | – | – |
| *Galium palustre* | $4^3$ | $1^2$ | $3^6$ | $1^2$ | $2^2$ | $4^3$ | – | $2^3$ | $5^7$ | $2^7$ | – | $2^3$ | – | $1^2$ | – | – | – | – |
| *Euphorbia palustris* | $4^2$ | – | – | – | – | – | – | – | – | $1^2$ | – | – | – | – | – | – | – | – |
| *Cladium mariscus* | – | – | – | – | – | – | – | – | – | – | – | $1^2$ | – | – | – | – | – | – |
| ***Oenanthion aquaticae*** | | | | | | | | | | | | | | | | | | |
| *Oenanthe aquatica* | – | $1^2$ | – | – | $1^2$ | $+^1$ | – | $1^1$ | – | $2^2$ | – | – | – | – | – | – | $+^1$ | – |
| ***POTAMETEA*** | | | | | | | | | | | | | | | | | | |
| *Potamogeton crispus* | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | $+^2$ | – |
| *Myriophyllum spicatum* | – | $1^2$ | $1^1$ | $2^1$ | $1^2$ | $+^3$ | – | $+^2$ | – | $1^2$ | $2^3$ | $1^1$ | – | – | $+^2$ | $5^8$ | $2^2$ | – |
| *Ceratophyllum demersum* | – | $1^2$ | – | – | – | $1^2$ | – | $1^2$ | – | $2^1$ | $2^2$ | $2^2$ | – | $1^2$ | $4^2$ | $3^2$ | $3^3$ | $5^9$ |
| *Potamogeton natans* | – | $1^2$ | – | – | – | – | – | $1^3$ | – | – | $2^2$ | – | – | $1^2$ | – | $2^2$ | $1^2$ | $1^2$ |
| ***Potametalia*** | | | | | | | | | | | | | | | | | | |
| *Myriophyllum verticillatum* | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | $+^1$ | – |
| *Hydrocharis morsus-ranae* | – | $+^1$ | – | – | – | – | – | – | – | – | $+^1$ | – | – | – | – | $1^1$ | – | – |
| ***Nymphaeion albae*** | | | | | | | | | | | | | | | | | | |
| *Potamogeton lucens* | – | $2^1$ | $1^2$ | $1^1$ | – | $2^1$ | – | $3^3$ | – | $1^1$ | $5^9$ | $3^4$ | – | $5^5$ | $4^2$ | $4^3$ | $3^2$ | $1^1$ |
| *Nymphaea alba* | $2^2$ | – | $1^1$ | – | – | – | – | $1^1$ | – | – | $1^1$ | $+^5$ | – | $5^8$ | $5^9$ | $2^2$ | $2^2$ | – |
| ***Parvopotamion*** | | | | | | | | | | | | | | | | | | |
| *Potamogeton trichoides* | – | $3^3$ | – | – | $+^2$ | – | – | $1^3$ | – | $1^3$ | $2^2$ | $2^2$ | – | $3^2$ | $4^2$ | $5^4$ | $5^8$ | $+^2$ |
| ***Ranunculion aquatilis*** | | | | | | | | | | | | | | | | | | |
| *Ranunculus trichophyllus* | – | $5^9$ | $4^4$ | $3^3$ | $2^2$ | $2^3$ | – | – | – | $1^4$ | $1^2$ | $+^1$ | – | – | – | $1^3$ | $1^2$ | – |
| *Utricularia australis* | $2^3$ | $2^2$ | $4^2$ | $4^3$ | $4^3$ | $3^3$ | $5^5$ | $5^4$ | $5^3$ | $5^3$ | $5^2$ | $5^4$ | $5^4$ | $5^4$ | $3^3$ | $3^2$ | $4^3$ | – |
| ***Potametalia*** | | | | | | | | | | | | | | | | | | |
| *Callitriche* sp. | – | $1^3$ | – | – | – | $+^1$ | – | – | – | – | – | – | – | – | – | – | – | – |
| *Myriophyllum alterniflorum* | – | – | – | $1^1$ | – | – | – | $+^1$ | – | – | – | – | – | – | – | – | – | – |
| ***MOLINIO-ARRHENATHERETEA*** | | | | | | | | | | | | | | | | | | |
| ***Lolio-Potentillion anserinae*** | | | | | | | | | | | | | | | | | | |
| *Agrostis stolonifera* | – | $3^3$ | $5^8$ | $5^9$ | $5^9$ | $5^9$ | $5^8$ | $4^5$ | $5^7$ | $2^3$ | $5^3$ | $4^3$ | $4^3$ | $2^2$ | $2^2$ | $1^3$ | $1^3$ | – |
| ***NERIO-TAMARICETEA*** | | | | | | | | | | | | | | | | | | |
| *Vitex agnus-castus* | – | – | – | – | – | $5^9$ | – | – | – | – | – | – | – | – | – | – | – | – |
| ***BIDENTETEA TRIPARTITI*** | | | | | | | | | | | | | | | | | | |
| *Ludwigia palustris* | $+^3$ | $2^3$ | $1^3$ | – | $1^2$ | $3^2$ | $5^8$ | $2^2$ | $+^1$ | $4^2$ | $+^1$ | $2^2$ | – | $3^2$ | $1^2$ | $1^1$ | $1^2$ | – |
| ***LEMNETEA*** | | | | | | | | | | | | | | | | | | |
| *Lemna trisulca* | – | – | – | – | – | – | – | – | – | $1^1$ | $+^2$ | $1^2$ | – | – | $1^2$ | – | $+^2$ | – |
| *Riccia fluitans* | – | – | – | – | – | – | – | – | – | – | – | $+^1$ | – | – | – | – | – | – |
| ***CHARETEA FRAGILIS*** | | | | | | | | | | | | | | | | | | |
| *Chara globularis* | – | $5^5$ | $2^2$ | $3^3$ | $1^2$ | $1^3$ | – | $1^3$ | – | $1^4$ | $1^3$ | $+^6$ | – | $4^2$ | $+^1$ | $3^2$ | $2^4$ | – |
| *Chara vulgaris* | – | $4^6$ | $3^3$ | $5^3$ | $+^2$ | $+^2$ | – | $+^1$ | – | – | – | – | – | – | $1^3$ | $1^2$ | $3^3$ | – |
| *Nitella* sp. | – | $1^2$ | – | – | $+^2$ | $+^3$ | – | – | – | – | $1^3$ | – | – | – | $1^6$ | $2^2$ | $2^4$ | – |
| *Tolypella* sp. | – | – | – | $1^2$ | $+^1$ | – | – | $1^2$ | – | $1^2$ | $1^2$ | $1^3$ | – | $1^2$ | $1^2$ | – | – | – |

Table 2. (Continued).

| **Cluster:** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **11** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Code of plant communities** | **C** | **R** | **SM** | **E** | **A** | **V** | **L** | **SL** | **G** | **PA** | **PL** | **T** | **P1** | **P2** | **N** | **M** | **PT** | **CD** |
| ***ISOËTO-LITTORELLETEA*** | | | | | | | | | | | | | | | | | | |
| *Apium inundatum* | – | – | – | – | – | – | – | $+^3$ | – | – | – | – | – | – | – | – | – | – |
| ***SCHEUCHZERIO-CARICETEA FUSCAE*** | | | | | | | | | | | | | | | | | | |
| *Epilobium palustre* | – | – | – | – | $1^2$ | – | – | $1^2$ | – | $1^2$ | – | $1^3$ | $5^3$ | – | – | – | – | – |
| *Veronica scutellata* | – | – | – | – | – | – | – | $+^3$ | $3^2$ | – | – | – | – | – | – | – | – | – |
| ***ISOËTO-NANOJUNCETEA*** | | | | | | | | | | | | | | | | | | |
| *Lythrum portula* | – | $1^3$ | $3^3$ | – | $1^2$ | $1^2$ | – | – | – | – | – | – | – | – | – | – | – | – |
| **Remaining species** | | | | | | | | | | | | | | | | | | |
| *Cyperus esculentus* | – | – | – | – | – | – | – | – | $1^2$ | – | – | – | – | – | – | – | – | – |
| *Gratiola officinalis* | – | – | – | – | $+^2$ | – | – | – | $5^9$ | – | – | – | – | – | $+^1$ | – | – | – |
| *Lysimachia nummularia* | – | – | $1^3$ | $1^1$ | – | $3^3$ | – | $1^2$ | – | $1^1$ | – | $1^2$ | $3^1$ | – | – | – | – | – |
| *Poa trivialis* | – | – | – | – | – | – | – | – | – | – | $+^1$ | – | – | – | $1^2$ | – | – | – |
| *Potamogeton coloratus* | – | $1^2$ | $1^2$ | – | $+^2$ | – | – | $1^2$ | – | $2^1$ | – | $+^1$ | – | – | – | – | $1^3$ | – |
| *Ranunculus ophioglossifolius* | – | $1^2$ | – | – | – | $1^3$ | – | – | $2^2$ | – | – | – | – | – | – | – | – | – |
| *Rorippa sylvestris* | – | $1^2$ | $1^2$ | – | $+^1$ | $1^2$ | – | – | – | – | – | $+^2$ | – | – | $+^1$ | – | – | – |
| *Rubus ulmifolius* agg. | – | – | – | – | – | $+^1$ | – | – | – | – | – | – | – | – | – | – | – | – |
| *Rumex conglomeratus* | – | – | – | – | – | – | – | – | $1^2$ | – | – | – | – | – | – | – | – | – |
| *Damasonium alisma* | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | $+^1$ | – |
| *Drepanocladus* sp. | – | – | $1^3$ | $2^3$ | $1^8$ | $+^2$ | – | – | – | – | $1^2$ | $+^2$ | – | $1^2$ | $+^1$ | – | – | – |
| *Chlorophyceae* sp. | – | $1^2$ | $1^5$ | $2^3$ | $2^2$ | $1^2$ | – | $1^2$ | – | – | $1^2$ | $+^2$ | – | $1^2$ | $1^3$ | – | $2^5$ | – |

For explanation of the codes of plant communities see Table 1. Constancy classes: + = 1–5%, 1 = 6–20%, 2 = 21–40%, 3 = 41–60%, 4 = 61–80% and 5 = 81–100%. The mean ordinal cover-abundance scale is given in superscript.

and has even been reported to grow in water 6 metres deep (Oberdorfer, 1990). The *Scirpetum lacustris* is more resistant to surge than the *Typho-Phragmitetum* (Weeda et al., 1995).

### *Alismo-Scirpetum maritimi* subass. *inops* (Cluster 3SM, Tab. 2, Vegetation mapping unit: 13)

**Syntaxonomy:** This cluster of relevés has been assigned to the *Alismo-Scirpetum maritimi,* because of the presence and high abundance of *Bolboschoenus maritimus* and the absence of halophytes (which characterize the *Halo-Scirpetum*) since there is no salt-water influence in Kalodiki.
**Differential species:** **Bolboschoenus maritimus* (dominant), *Oenanthe fistulosa*, *Lythrum portula.*
**Constant species:** *Ranunculus trichophyllus, Utricularia australis* and *Agrostis stolonifera.*
**Ecology:** The *Alismo-Scirpetum* is typical of very iron-rich, fresh or brackish water and grows on mineral and peat soils. The typical subassociation indicates strong fluctuations in the water table.

### *Typho-Phragmitetum typhetosum angustifoliae* (Cluster 12T, Tab. 2, Vegetation mapping unit: 3)

**Syntaxonomy:** The community can be recognized by the presence of *Typha angustifolia* and *Phragmites australis.* Two subassociations occur in Kalodiki: the *typhetosum angustifoliae* dominated by *Typha angustifolia* and the typical subassociation. The first one is positively differentiated against the *typicum* by the hydrophytes *Potamogeton lucens* and *Ludwigia palustris.*
**Differential species:** **Typha angustifolia* is a common differential species for this association and also for the transition between *Typho-Phragmitetum, Potametum lucentis* and *Myriophyllo-Nupharetum.* It however only dominates in this vegetation type (12T).
**Constant species:** *Agrostis stolonifera*, *Utricularia australis.*
**Ecology:** The ecological conditions are similar with the prevailing ones in habitats of the *Typho-Phragmitetum typhetosum angustifoliae*, except for the water depth (0.5–3 m). The *typhetosum* is most frequent in waters with depth of 0.5–1.5 m.

### *Typho-Phragmitetum* subass. *typicum* (Cluster 13P1, Tab. 2, Vegetation mapping unit: 11)

**Syntaxonomy:** This cluster has been assigned to the subassociation *Typho-Phragmitetum typicum* because of the presence of the character taxa *Typha angustifolia*, *Phragmites australis* and the grassland species *Epilobium palustre.*
**Differential species:** **Epilobium palustre.*
**Constant species:** *Phragmites australis, Agrostis stolonifera* and *Utricularia australis.*
**Ecology:** The *Typho-Phragmitetum* grows in 0.5–3 m deep, meso- to eutrophic water, in mineral or peaty soil with a thick layer of sapropelium. The subassociation occupies water depth from 0.5 to 3 m. It is optimally developed in fens and oxbow lakes, preferably where water movement is absent or slow and where fertilization, pollution and grazing are absent.

***Eleocharitetum palustris* (Cluster 4E, Tab. 2, Vegetation mapping unit: 14)**

**Syntaxonomy:** This cluster is assigned to the association *Eleocharitetum palustris* because of the presence and relatively high cover of *Eleocharis palustris* subsp. *palustris* (Schubert et al., 1995).
**Differential species:** **Eleocharis palustris*.
**Constant species:** *Agrostis stolonifera, Chara vulgaris* and *Utricularia australis*.
**Ecology:** This association grows in fluctuating, standing or running water up to 50 cm deep and can be present on disturbed banks for many years (Pott, 1992, Rodwell et al., 1995). Spatially it grows on the edges of Kalodiki Fen, which are almost dry in August.

**Ib) *Magnocaricion elatae***

***Caricetum gracilis* (Cluster 1C, Tab. 2, Vegetation mapping unit: 12)**

**Syntaxonomy:** This cluster was assigned to the association *Caricetum gracilis* due to the presence of the dominant *Carex acuta* and the constant *Galium palustre* (Weeda et al., 1995).
**Differential species:** **Carex acuta* (dominant), **Euphorbia palustris*, **Lysimachia vulgaris, Lythrum salicaria*.
**Constant species:** *Galium palustre*.
**Ecology:** It is restricted to eutrophic, stagnant or slowly flowing water. It grows on mineral grounds, but also exists on thick peat layers (Weeda et al., 1995). In Kalodiki Fen the *Caricetum gracilis* grows on peat where it often forms tall tussocks. It is a strong competitor during anaerobic flooded periods, but also during drier periods (Pott, 1992).

**II) *Potametea***

Three associations and three frame communities represent the freshwater aquatic vegetation of the *Potametea*.

**Frame community of *Myriophyllum spicatum* – [*Potametea*] (Cluster 16M, Tab. 2, Vegetation mapping unit: 2)**

**Syntaxonomy:** This cluster has been assigned to this community due to the dominance of *Myriophyllum spicatum* and the local presence of *Ceratophyllum demersum*. It is very often accompanied by *Potamogeton trichoides* and *P. lucens*.
**Differential species:** **Myriophyllum spicatum*.
**Constant species:** *Potamogeton trichoides* and *P. lucens*.
**Ecology:** This community occurs in open water in the SE part of the wetland. According to the literature it grows in fresh, clear, meso- to eutrophic and moderately hard to very hard waters with a relatively low amounts of phosphate (De Lange, 1972, Rodwell et al., 1995) and high sodium and magnesium contents (Papastergiadou, 1990).

***Potametalia***

**Frame community of *Ceratophyllum demersum* – [*Potametalia*] (Cluster 18CD, Tab. 2, Vegetation mapping unit: 10)**

**Syntaxonomy:** This cluster of relevés has been assigned to the frame community due to the dominance of *Ceratophyllum demersum*.
**Differential and constant species:** *Ceratophyllum demersum*.
**Ecology:** It occurs in some deep open waters of the Kalodiki wetland. It is common in river and moor areas where it forms closed vegetation in sheltered, usually eutrophic to polytrophic waters (Schaminée et al., 1995; Schubert et al., 1995). It can be found situated behind other communities in open waters and near pollution sources (Schipper et al., 1995). The water depth varies between 0.5 and 10 m (Oberdorfer, 1990).

***Nymphaeion albae***

***Potametum lucentis* (Cluster 11PL, Tab. 2, Vegetation mapping unit: 8)**

**Syntaxonomy:** This cluster of relevés has been assigned to the *Potametum lucentis* of the *Nymphaeion albae*, due to the presence of the character-species *Potamogeton lucens* in combination with the constant species *Agrostis stolonifera* and *Utricularia australis*.
**Constant species:** *Potamogeton lucens* (dominant), *Agrostis stolonifera* and *Utricularia australis*.
**Ecology:** In Kalodiki Fen this vegetation unit grows between the dense *Typho-Phragmitetum typhetosum angustifoliae* described above, and the more aquatic vegetation of the *Potametea*. The *Potametum lucentis* has its optimum in deep lakes, old rivers and canals with stagnant, eutrophic, clear, moderately iron- and carbonate-rich water. The water depth varies in general between 1-3 m and this association bears water movement well. This vegetation unit frequently grows on peaty soils with a layer of sapropelium (Schipper et al., 1995). According to Pott (1992), a high concentration of $CaCO_3$ can cause hardening of the leaves of *Potamogeton lucens* with calcium, which is also the case in the Kalodiki wetland.

***Myriophyllo-Nupharetum* (Cluster 15N, Tab. 2, Vegetation mapping unit: 4)**

**Syntaxonomy:** This cluster of relevés has been assigned to the *Myriophyllo-Nupharetum* of the *Nymphaeion* due to the presence of the character-taxon

*Nymphaea alba* and the constant species *Ceratophyllum demersum.* As it is accompanied by the constant species *Ceratophyllum demersum*, this vegetation is assigned to the *Nymphaea alba* variant (SCHIPPER et al., 1995) of the *Myriophyllo-Nupharetum*.

**Differential species:** **Nymphaea alba* is a common differential species for this plant community and for the transitional vegetation unit between *Typho-Phragmitetum, Potametum lucentis* and *Myriophyllo-Nupharetum.* However, it is only the dominant species of this community.

**Constant species:** *Ceratophyllum demersum, Potamogeton lucens* and *P. trichoides.*

**Ecology:** In Kalodiki wetland only a few, deeper sites occur where the vegetation is dominated by *Nymphaea alba.* This association occurs in meso- to eutrophic waters and is optimally developed into nutrient rich, (bi) carbonate rich water. When considering the water quality amplitude, it varies considerably but avoids brackish water. The water level is also very variable (up to 2 m), with optimal water depth of about 1.2 m (SCHIPPER et al., 1995). The unit is sensitive to large, dynamic changes in water level (VAHLE & PREISING, 1990).

### *Parvopotamion*

#### Frame community of *Potamogeton trichoides* – [*Parvopotamion*] (Cluster 17PT, Tab. 2, Vegetation mapping unit: 6)

**Syntaxonomy:** This cluster of relevés has been assigned to the frame community of *Potamogeton trichoides*, due to the presence of the dominant species *Potamogeton trichoides* in combination with *Utricularia australis.*

**Differential species:** **Potamogeton trichoides* is a common differential species for this plant community and for the transition between *Typho-Phragmitetum, Potametum lucentis* and *Myriophyllo-Nupharetum.* However, it only dominates in this community.

**Constant species:** *Utricularia australis.*

**Ecology:** This frame community is very common in moor and sand areas (SCHIPPER et al., 1995). It grows in phosphate poor (DE LANGE, 1972), clear, base rich and mesotrophic to eutrophic water with strongly fluctuating water levels (POTT, 1992; VAHLE & PREISING, 1990) and water depths of 1–2 m (SCHUBERT et al., 1995). In the SW part of Kalodiki the frame community of *Potamogeton trichoides*-[*Parvopotamion*] occurs.

### *Ranunculion aquatilis*

#### *Ranunculetum aquatilis* (Cluster 2R, Tab. 2)

**Syntaxonomy:** This relevé cluster has been assigned to the *Ranunculetum aquatilis* because of the dominance of *Ranunculus trichophyllus* and the presence of *Chara globularis* and *Ch. vulgaris.* In April and May, the conspicuous and beautiful white flowers of *Ranunculus aquatilis* var. *diffusus* cover the more open water at the border of the wetland. *R. trichophyllus* belongs to a variable complex and is sometimes difficullt to distinguish from *R. aquatilis* L., which is widespread in C and W Europe but apparently does not occur in Greece (STRID & TAN, 2002).

**Differential species:** **Ranunculus trichophyllus.*

**Constant species:** *Chara globularis* and *Ch. vulgaris.*

**Ecology:** It grows in carbonate-rich (POTT, 1992) and eutrophic, non shaded, easily warmed shallow and temporarily emerging water-bodies (SCHUBERT et al., 1995). The *Ranunculetum aquatilis* can withstand large fluctuations in water level and dry periods (SCHUBERT et al., 1995).

## III) Transitional vegetation types between the *Phragmito-Magnocarietea* and *Potametea* (Cluster 14P2, Tab. 2, Vegetation mapping unit: 15)

**Syntaxonomy:** A considerable part of Kalodiki surface is covered by a transition between the *Typho-Phragmitetum*, *Potametum lucentis* and *Myriophyllo-Nupharetum.* This vegetation type is characterized by the co-occurrence of *Phragmites australis*, *Typha angustifolia*, *Potamogeton lucens* and *Nymphaea alba* (SCHAMINÉE et al., 1995) and is consequently assigned to a transitional unit.

**Differential species:** **Typha angustifolia* when regarding this community together with *Typho-Phragmitetum typhetosum angustifoliae* (cluster 12T), and *Nymphaea alba* when regarding this community together with *Myriophyllo-Nupharetum* (cluster 15N).

**Constant species:** *Phragmites australis*, *Potamogeton lucens*, *Nymphaea alba, Chara globularis.*

**Ecology:** This vegetation unit is found in relatively deep waters down to 3.5 m. This transitional community covers the central part of the fen. The *Typho-Phragmitetum* appears in mesotrophic to eutrophic water, with water depths varying from 0.5 to 3 m, while the other two associations occur in deep, eutrophic water (SCHAMINÉE et al., 1995).

## IV) *Molinio-Arrhenatheretea*

#### Frame community of *Agrostis stolonifera* – [*Potentillion anserinae*] (Cluster 5A, Tab. 2, Vegetation mapping unit: 9)

**Syntaxonomy:** This relevé cluster has been assigned to the frame community of *Agrostis stolonifera*-[*Lolio-Potentillion anserinae*] because of the dominance and high presence of *Agrostis stolonifera* (SÝKORA et al., 1996).

**Constant species:** *Agrostis stolonifera* and *Utricularia australis*

**Ecology:** It occurs on relatively nutrient rich grasslands that are flooded for long periods of time, where the sensitive plant species disappear due to strong environmental (mostly anthropogenic) dynamics. *Agrostis stolonifera* can survive and is even stimulated by intensive grazing (SÝKORA, 1982). The frame community appears on sandy, clay, mineral and peaty soils and secondary inundation during the season is well tolerated (SÝKORA, 1983; SÝKORA et al., 1996). It occurs mainly in the SW part of Kalodiki and is grazed by goats. In spring, the water level drops abruptly and the vegetation emerges for a long period.

### Community of *Gratiola officinalis* [*Lolio-Potentillion anserinae/Magnocaricion elatea*] (Cluster 9G, Tab. 2, Vegetation mapping unit: 16)

**Syntaxonomy:** The vegetation unit assigned to the community of *Gratiola officinalis* occurs at the edge of grassland grazed by sheep. The aspect of *Potentillion anserinae* is represented by the presence of the character species *Agrostis stolonifera* (SCHAMINÉE et al., 1996) while the aspect of *Magnocaricion elatae* is represented by the presence of the character species *Galium palustre* and *Veronica scutellata* (HORVAT et al., 1974). This species combination indicates a transition between the two alliances *Lolio-Potentillion anserinae* and *Magnocaricion elatae.* It is further characterized by *Utricularia australis* and *Baldellia ranunculoides.*
**Differential species:** **Gratiola officinalis* (dominant), **Baldellia ranunculoides*, *Veronica scutellata.*
**Constant species:** *Galium palustre*, *Agrostis stolonifera, Utricularia australis.*
**Ecology:** *Gratiola officinalis* is a species of winter-flooded grasslands, where it grows on sandy to clayey banks. The plant tastes very bitter and is poisonous (WEEDA et al., 1985). In the Netherlands, *Gratiola officinalis* occurs in communities, bound to wet to moist, mesotrophic to eutrophic, fresh soils, which may be flooded during a considerable part of the year (RIJPERT, 1977). In Central Europe the species is considered a character species of the *Cnidion dubii* BALÁTOVÁ-TULÁČKOVÁ 1965 (*Molinietalia*), which includes hay meadows in floodplains with strongly fluctuating water levels, fertilized by sediments deposited during high water inundation. Trophically, this unit takes a position between the more nutrient rich *Calthion palustris* and the less nutrient rich *Molinion* (ELLENBERG, 1996).

## V) *Nerio-Tamaricetea*

### *Vitex agnus-castus* scrub of the community *Nerium-Tamarix tetrandra* (Cluster 6V, Tab. 2, Vegetation mapping unit: 7)

**Syntaxonomy:** This cluster has been assigned to the *Vitex agnus-castus* scrub of the community *Nerium-Tamarix tetrandra* due to the presence of the character species *Vitex agnus-castus* (HORVAT et al., 1974). *Vitex agnus-castus* is a shrub up to 6m in height, which is considered a character-species of the *Nerium-Tamarix tetranda* community of the *Tamaricetalia africanae*, as described by KRAUSE et al. (1963).
**Differential species:** **Vitex agnus-castus* (dominant).
**Constant species:** *Galium palustre, Agrostis stolonifera.*
**Ecology:** In shallow water bordering the fen's shores, brushwood dominated by *Vitex agnus-castus* grows locally. The brushwood is common in damp places and periodically flooded sandy banks, on the littoral zones of lakes and stream banks (HORVAT et al., 1974). In August the area surrounding the fen is coloured pale lilac by the flowers of *Vitex agnus-castus.*

## VI) *Bidentetea tripartiti*

### Community of *Ludwigia palustris* (Cluster 7L, Tab. 2, Vegetation mapping unit: 17)

**Syntaxonomy:** According to WESTHOFF & DEN HELD (1969), *Ludwigia palustris* is a character species of the *Ludwigietum palustris,* a community they assigned to the *Bidention tripartitae.* According to WEEDA et al. (1998), this association is no longer accepted and they comment that even if this association were maintained, it certainly would not belong to the *Bidentetea.* In Central Europe, *Ludwigia palustris* is considered to be a character species of the *Elatino-Eleocharitenion ovatae, Nanocyperion* (OBERDORFER, 1990; ELLENBERG, 1996). The *Ludwigia palustris* community growing in Kalodiki is very atypical for an *Elatino-Eleocharitenion,* since no other characteristic species of this suballiance occur. Rather, it is a mixture of the two co-dominant species *Ludwigia palustris* and *Agrostis stolonifera*, mixed with *Utricularia australis.* According to OBERDORFER (1990), *Ludwigia palustris* occurs in the *Bidention tripartitae* and the *Littorelletea.*
**Differential and constant species:** None.
**Ecology:** This community occurs in marshlands grazed by geese and eutrophicated mire pools that rarely dry out. According to WEEDA et al. (1985) it only appears in carbonate-poor, phosphate-poor and nitrate-rich waters. In Kalodiki, only the SW part of the fen has real dominance of *Ludwigia palustris*, but the taxon has lower densities in other areas of the fen.

*Relation between species composition and environmental parameters*

Water depth, moisture, nutrients, pH

When using the Monte Carlo permutation test with forward selection, it appears that all environmental factors are significant at a significance level $< 0.01$ except for pH, and the order of factors explaining the species composition is: a) moisture, b) water depth, c) nitrogen, d) pH (not significant). The species composition of the dis-

Table 3. Correlations of environmental factors (depth, moisture, pH, nitrogen) with the first four CCA axes, Eigenvalues of the ordination axes and sum of all unconstrained Eigenvalues (total inertia) for a CCA analysis of the cluster centroids of the distinguished plant communities in Kalodiki Fen.

| Factor | Axis 1 | Axis 2 | Axis 3 | Axis 4 | Total inertia |
|---|---|---|---|---|---|
| Depth | 0.8178 | 0.4229 | 0.0383 | 0.2911 | |
| Moisture | 0.8973 | −0.3150 | −0.1861 | 0.1085 | |
| pH | 0.4092 | 0.1101 | −0.1422 | −0.8055 | |
| Nitrogen | 0.7940 | −0.1101 | 0.3894 | −0.3701 | |
| Eigenvalue | 0.61 | 0.57 | 0.38 | 0.26 | 5.284 |

Table 4. Ordering of Kalodiki plant communities following a water depth gradient.

| Mean depth | Vegetation unit |
|---|---|
| Up to 1 m | *Alismo-Scirpetum maritimi* |
| | *Gratiola officinalis* community |
| | *Vitex agnus-castus* scrub |
| Up to 1.5 m | *Eleocharitetum palustris* |
| | *Ranunculetum aquatilis* |
| | *Typho-Phragmitetum typicum* |
| | Frame community of *Agrostis stolonifera* |
| | Frame community of *Phalaris arundinacea* |
| Up to 2 m | *Scirpetum lacustris* |
| | *Typho-Phragmitetum typhetosum angustifoliae* |
| | Community of *Ludwigia palustris* |
| | Frame community of *Myriophyllum spicatum* |
| | Frame community of *Potamogeton trichoides* |
| Up to 2.5 m | *Caricetum gracilis* |
| | *Potametum lucentis* |
| | *Myriophyllo-Nupharetum* |
| | Transitional community (between *Typho-Phragmitetum, Potametum lucentis* and *Myriophyllo-Nupharetum*) |
| About 3.5 m | Frame community of *Ceratophyllum demersum* |

tinguished plant communities is clearly related to water depth and to Ellenberg indicator values for moisture and nitrogen.

When running a Canonical Correspondence Analysis with moisture, depth, nitrogen and pH as environmental parameters, the coefficients of determination ($r^2$) are high. The results in Tab. 3 show that axes 1 and 2 represent a great amount of explanatory value. Axis 3 and the following were not interpreted.

Water depth and moisture explain 67% and 81% of the species composition respectively. Acidity is hardly discriminating between the communities and explains only 17% of the species composition. In all communities the water is alkaline. The water depth was measured for each plant community at the beginning of May. In Fig. 3, the reduction in water level from the beginning of May to the beginning of July is schematically represented. During this period the water level dropped 30 cm and up to 1 cm a day.

The relation between each plant community and water depth is shown in Figs 4 and 5. In Fig. 5 the relation between the water depth of the different communities and their position along the first axis of a CCA is given. The correlation between the main variation in the species composition and the mean water depth is clearly visible. Following the water depth gradient the communities could be ordered as shown in Tab. 4.

The difference in electric conductivity between the plant communities appears to be insignificant. The mean conductivity for all plant communities is low (252 $\mu$S/cm, S.D. 41) indicating the unpolluted character of the water. Electric conductivity can be used as a rough measure of the total nutrient status of the water. It should be emphasized that it can only give an idea of the momentary status and not of the nutrient flow. As a rule, total conductivity is lower in winter; this must be considered when conductivity values are compared (Verhoeven, 1992a).

*Nutrient status of the fen*

The mean nitrogen values are correlated to water depth and moisture ($r^2 = 0.51$ and 0.64 respectively) suggesting an increase in nutrient availability with increased water depth. Based on these figures, the communities are given according to their general nutrient supply in Tab. 1.

*Ordination*

Of the examined environmental variables, the longest arrows represent water depth, moisture and nitrogen and this means that they are more closely correlated with the main variation in species composition as represented by the cluster centroids of the distinguished plant communities. All variables are mainly related to the first axis, as is also expressed by the $r^2$ scores (Tab. 3). Nitrogen and moisture values are correlated, while the correlation between moisture and water depth is poor. The latter can be explained by the fact that all water plant communities are consequently wet and the moisture figure only varies in the (semi) terrestrial environment.

From the upper left side to the lower right side of the ordination diagram (Fig. 6) a gradient can be distinguished from relatively nutrient poor and moist to more nutrient rich and wet communities. Communities from relatively nutrient-poor sites (Ellenberg indicator value: 4), score at the left and most distant part of the diagram (i.e. *Caricetum gracilis*: 1C, community with *Gratiola officinalis*: 9G). A tight group of cluster centroids with intermediate nutrient availability (Ellenberg value: 5) is assembled in the left part of the diagram (i.e. community of *Ludwigia palustris*: 7L, *Eleocharitetum palustris*: 4E, *Vitex agnus-castus* scrub: 6V).

The relatively nutrient rich communities are plotted close to the top of the arrow, i.e. *Myriophyllo-Nupharetum* (15N), *Potametum lucentis* (11PL), frame com. of *Potamogeton trichoides* (17PT), frame com. of *Myriophyllum spicatum* (16M) and the frame com. of *Ceratophyllum demersum* (18CD).

The communities that are periodically submerged such as *Gratiola officinalis* community (9G), *Vitex agnus-castus* scrub (6V) and *Alismo-Scirpetum maritimi* (3SM), are drawn at the left side of the arrow. The submerged communities are situated at the end of the arrow. This applies for the frame communities of *Ceratophyllum demersum* (18CD), *Myriophyllum spicatum* (16M), and *Potamogeton trichoides* (17PT).

Along the water depth gradient, the communities are positioned in the ordination from the lower left part to the upper right part of the ordination diagram. The order of the communities along this gradient corresponds to their relation with water depth as given in Table 4. The *Ceratophyllum demersum* community that occurs in very deep, eutrophic water is located at the top of the arrow representing the water depth.

The behavior of the *Caricetum gracilis* (1C) plotted at the drier side of the diagram, but occurring in water depths of up to 2.5 m can be explained. *Carex gracilis* is usually a shoreline species and as such a species with relatively low Ellenberg moisture value. In Kalodiki Fen however, *C. gracilis* grows on self-developed exceptionally tall tussocks.

## Concluding remarks

Wetlands of ecological importance are getting increasingly rare in the Mediterranean. In addition, Greek wetlands are severely threatened and of these, the remaining lakes should urgently be conserved. This certainly applies for Kalodiki Fen.

According to Sarika-Hatzinikolaou et al. (2003), seven associations and three communities are referred from Kalodiki Fen, and these are assigned to the following alliances: *Hydrocharition, Nymphaeion albae, Phragmition communis, Potamogetonion pectinati* and *Ranunculion acuatilis.* Sarika-Hatzinikolaou et al. (2003) documented for the first time (with published relevés) the presence of *Eleocharitetum palustris* in Greece, specifically from Lake Pamvotis (District of Ioannina, Epirus). Its presence in Kalodiki Fen is the second record of this association in Greece.

From our small scale vegetation survey, which revealed a much higher number of vegetation types occurring in Kalodiki fen (eighteen units, of which nine are ranked as associations and nine as frame communities), it is obvious that the studied fen is a relatively heterogeneous wetland with small-scale variation. Kalodiki's vegetation is characterised by well-developed swamp, mesotrophic and eutrophic freshwater, aquatic plant communities, as a mosaic in various combinations of spatial arrangement. The diversity of the wetland vegetation habitats, based on the number of syntaxonomic units recognized within the major vegetation types decreases in the following order: swamp and fen vegetation dominated by graminoids, sedges and forbs (8) → communities of rooted, floating or submerged macrophytes in mesotrophic and eutrophic fresh waters (6) → low herb communities of variable habitats with wet-dry, or brackish-fresh conditions (2) → communities of enriched margins of still or sluggish waters and damp disturbed places (1) → tamarisk woodlands on soils inundated with fresh water (1).

The ecological state of the whole ecosystem is strongly dependent on a small dam. Farmers often damage the dam in order to irrigate their fields. The dam is badly maintained and leaks.

When water levels exceed 4 m, the *Phragmito-Magnocaricetea* communities disappear, while *Potametea* communities disappear when the level drops below the soil surface. Georgiadis (1994) proposed to increase the water level of the basin to 109.5 m above sea level, by restoring full impermeability of the present dam. This will approximately result in a yearly mean water level of 2 m in the middle of the fen, allowing the maintenance of most of the existing plant communities. However, disappearance of emergent plants and their communities due to excessively high water levels would influence bird species by the absence of breeding places (Gerakis, 1992).

The water level should always be kept above the soil level in order to prevent the oxidation of the peat layer. Thus, the ecological role of the fen would be upgraded and simultaneously the water of the fen could be used to irrigate the cultivated plain of Margariti and supply potable water. Eutrophication caused by erosion, agriculture and pollution has to be prevented. The awareness of the local population on the value of Kalodiki wetland should be raised. Illegal local activities such as hunting, rubbish dumping, cultivation of the wetland, and destruction of the dam should be prevented by control.

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