

Ecological profiles of wetland plant species in the northern Apennines (N. Italy)

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ABSTRACT

Eighteen selected species occurring in the wetlands of the northern Apennines were studied by the ecological profile method. By this method, it is possible to identify the ecological factors mostly influencing species distribution within a particular vegetation. Moreover, it is possible to evaluate both ecological amplitude and ecological preferences of species. Ecological profiles were built for three factors (altitude, pH and electrical conductivity) from a data set of 265 phytosociological relevés, used for altitude, and from a set of 92 measures, carried out in selected sites, for hydrochemical variables. By numerical classification, based on chord distance and minimum variance, the ecological species groups for each factor were individuated. Subsequently, they were ordered by correspondence analysis for detecting relationships between ecological groups and classes of factors. By applying a goodness-of-fit test to ecological profiles, the species significantly deviating from uniformity were detected. They can be regarded as indicators for the corresponding ecological factor. We found seven indicator species for altitude (*Carex nigra*, *C. rostrata*, *Juncus filiformis*, *J. alpino-articulatus*, *Eriophorum latifolium*, *E. angustifolium* and *Warnstorfia exannulata*), four indicator species for electrical conductivity (*Campyllum stellatum*, *Carex tumidicarpa*, *Eriophorum latifolium* and *Juncus alpino-articulatus*) and one indicator species for pH (*Sphagnum capillifolium*). The ecological profiles of the wetland species in the northern Apennines were compared with those reported in literature for the same species from the Alps (namely Dolomites). In this way, a certain degree of ecological shift in several wetland species of the northern Apennines was documented. For altitude, it is possible to explain the shift considering the reduced elevational amplitude of northern Apennine wetlands with respect to those of the Alps. For pH, *Sphagnum capillifolium* occurs in less acidic habitats than in the Alps, probably due to the absence of ombrotrophic mires, and *Viola palustris* occurs mostly in neutro-basiphytic habitats. Some hypotheses to explain the ecological behaviour of this last species were proposed.

Keywords: ecological profiles, statistical multivariate analysis, indicator species, mountain wetlands, northern Apennines

1. INTRODUCTION

The analysis of species-environment relationships and the identification of indicator species are traditional activities in ecology. Bioindicators can be defined as species whose presence or abundance readily reflect some measure of the character of the habitat within which they are found (McGeoch & Chown 1998). Besides its prime importance as a research tool in autoecology, the quantification of species-environment relationships recently gained importance as a tool to control the distribution of species and communities, to test biogeographical hypotheses, or to set up conservation priorities (Guisan & Zimmermann 2000).

In recent years, there has been an increasing interest in defining the relationships between the occurrence of plant species and site conditions, using response modelling. The primary aim of most studies is to acquire more insight into the distribution of species along a gradient, to determine which variables affect the presence or absence of species and to investigate in what way the prediction of species could be improved (Austin 1990; Yee & Mitchell 1991; Huisman *et al.* 1993; Austin & Gaywood 1994).

In plant ecology one of the method currently used by European scientists to investigate the species-environment relationships is the ecological profile method

(Gounot 1958, 1969; Godron 1966, 1968; Guillermin 1971). By this method, it is possible to transform data resulting from vegetation analyses and environmental measures into ecological profiles. The analysis of ecological profiles by information theory allows to test the predictivity of ecological factors and the indication power of species. In other words, this method allows to evaluate the affinity and significance of the association between probability of species occurrence and environmental factors (Daget & Godron 1982).

The ecological profile method is a powerful instrument to recognize indicator species and it has been tested and used by several authors in different habitats (Gounot 1958; Guillermin 1969a, 1969b; Ferrari & D'Antuono 1983; Guillermin & Sutisna 1983; Haury 1995; Vasconcellos *et al.* 1999; Devineau 2001; Zas & Alonso 2002). Nevertheless, this method has been hitherto scarcely employed to study mountain wetland vegetation and there are few works concerning the ecological profiles of the species growing on these habitats (Gerdol & Bragazza 1994; Gerdol & Tomaselli 1997).

In particular, there are no works focused on the wetland vegetation of the northern Apennines, in spite of its phytogeographic and conservation interest, due to the occurrence of boreal species lying at the very southern border of their distributional area in Europe. Some of these species have their ecological space dramatically

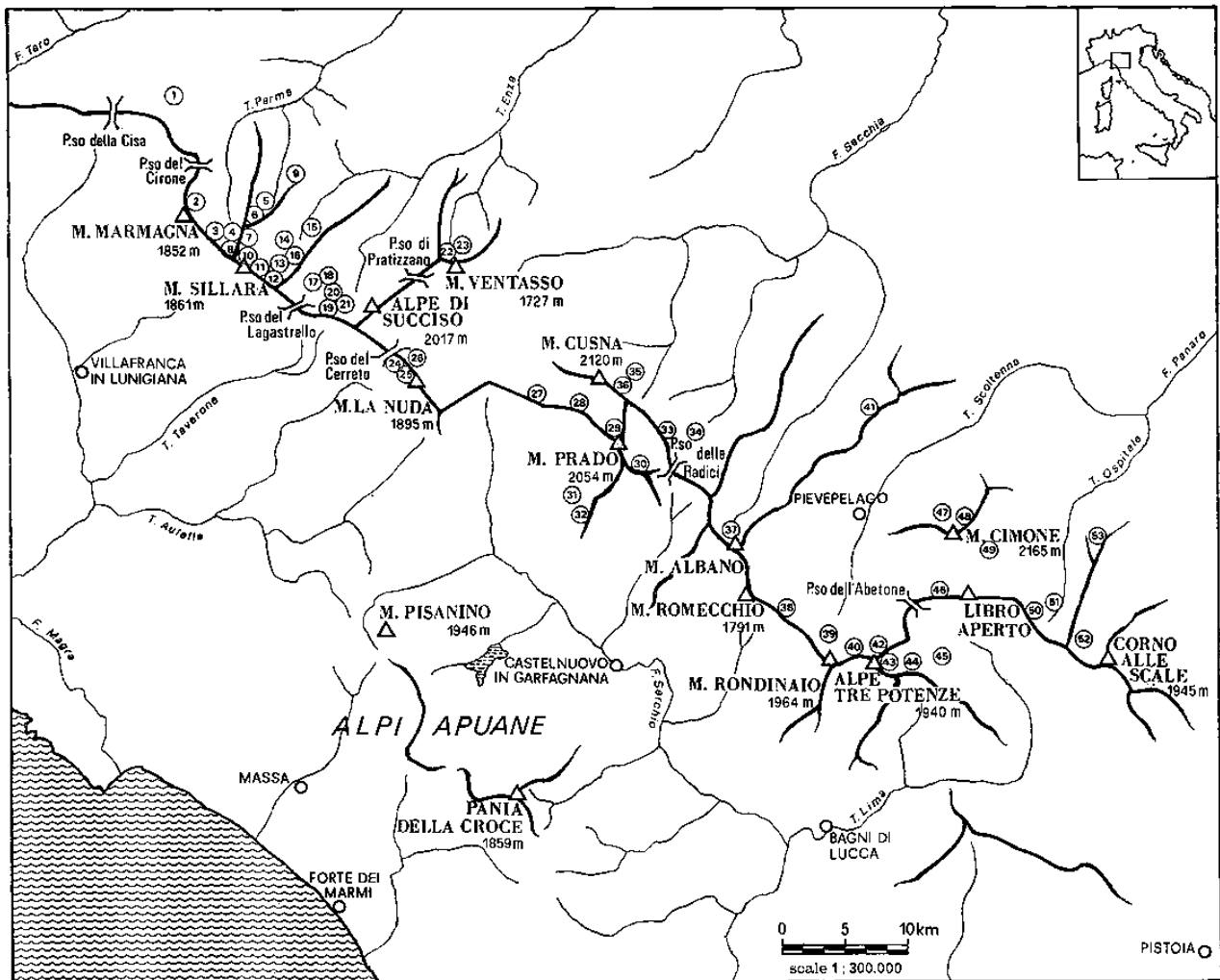


Fig. 1. Map of the study area. Figures indicate the wetlands surveyed.

reduced with respect to northern regions, whereas others have better opportunities to extend their ecological niche as a consequence of the floristic impoverishment (Gerdol & Tomaselli 1993).

The present paper is a first attempt to define the ecological profiles of wetland vascular plants and bryophytes in this mountain area, characterised by a scarcity of studies on wetland plant ecology. Moreover, the paper aims at: i) identifying local indicator species useful in the fields of nature monitoring, conservation and management; ii) verifying and quantifying shifts in the ecological optima of wetland species with respect to northern regions, particularly to the Dolomites studied by Gerdol & Tomaselli (1997).

2. STUDY AREA

The study area corresponds to the sector of the northern Apennines comprised between Cisa Pass and the valley of Reno river. This sector of the Apennines, nearly 150 km long, separates the Po plain northwards

from the Italian peninsula southwards and has only few summits exceeding 2000 m (Fig. 1).

The geological substratum mainly consists of thick-bedded turbiditic sandstones and marls (upper Oligocene – lower Miocene), corresponding to the "Macigno" formation (Dallan Nardi & Nardi 1974). The gently shelving northern slope is characterised by glacial landforms originated during Pleistocene (Losacco 1982), but still evident nowadays. In contrast, the southern slope is much steeper and shows only poor traces of glacial morphology.

The climate in the study region can be defined as temperate montane. At 1000 m the mean annual temperature is *ca* 9 °C, that of January *ca* 1 °C and that of July 18 °C. On the summit (M. Cimone, 2165 m) the mean annual temperature is 2.1 °C, that of January –4.3 °C and that of July 10.3 °C. Precipitation is more abundant on the southern slope, influenced by the Tyrrhenian Sea, than on the more continental northern slope. At 1000 m the mean annual rainfall is *ca* 2300 mm on the S

Tab. 1. Numbers from I to VI represent the class intervals for each factor considered, as defined for ecological profiles analysis.

Class Intervals	I	II	III	IV	V	VI
Altitude (m a.s.l.)	≤ 1300	1301 - 1400	1401 - 1500	1501 - 1600	1601 - 1700	> 1700
pH	≤ 5.10	5.11 - 5.70	5.71 - 6.30	6.31 - 6.90	> 6.90	-
Conductivity (μS cm ⁻¹)	≤ 40	41 - 80	81 - 120	> 120	-	-

slope and *ca* 1400 mm on the N slope. On the summit there are only 750 mm.

Wetlands in the northern Apennines usually represent more or less evolved dynamics stages in the filling-up process of lakes. Most of these lakes are clearly related to glacial morphology, for being located either at the bottom of glacial cirques or between morainic arches (Carton & Panizza 1988). There are, moreover, small shallow pools originated by differential erosion of looser nuclei of sandstone. A big majority of wetlands in the northern Apennines are located above 1000 m and specially around 1500 m, at the mean altitude of the bottom of glacial cirques, inside a vegetation belt (montane belt) dominated by *Fagus sylvatica* forests.

The wetland vegetation in the northern Apennines includes eighteen different plant communities (Gerdol & Tomaselli 1993), belonging to the following main vegetation typologies: 1) water-plant communities; 2) riparian helophytic communities; 3) mire vegetation with fens, *Sphagnum* mats and *Sphagnum* hummocks; 4) wet-meadow communities.

3. MATERIALS AND METHODS

The data set for this paper, derived from Gerdol & Tomaselli (1993), consists of 265 phytosociological relevés, taken from 53 different sites and of 92 water chemistry measures (of pH and electrical conductivity), carried out with portable instruments at some selected relevé sites.

Data processing was carried out by means of the ecological profile method (Daget & Godron 1982). The following three ecological factors, affecting distribution of plant species in mountain wetlands according literature (e.g., Dierssen 1982, 1996; Sjörs 1983; Malmer 1986; Økland 1990), were considered for the calculation of the ecological profiles: i) altitude, reflecting the temperature gradient; ii) pH; iii) electrical conductivity. The data set for ecological profiles comes from 265 relevés for altitude, and from 92 relevés for pH and electrical conductivity.

The ecological profiles were calculated for only 18 species, selected choosing, among the species belonging to the characteristic combination (Braun-Blanquet 1964) of all wetland vegetation units, only the ones occurring in more than 7% of the whole relevé set.

Each ecological factor was subdivided into different numbers of classes of equal amplitude. Intervals of factor classes are reported in table 1. In order to obtain an

estimate of the degree of information provided by the factors in relation to the species as a group, the entropy factor was expressed in terms of the mean of the joint species-factor information. The factors with greatest mutual species-factor information values are the "effective" ones (Daget & Godron 1982). Joint species-factor information and entropy factor were calculated as in Daget & Godron (1982).

Corrected frequencies (CF) were calculated for the 18 selected species as follows:

$$CF = \frac{U(K)/R(K)}{U(S)/N} \quad (1)$$

where $U(K)$ = occurrences of species S in factor class K , $U(S)$ = total number of occurrences of species S , $R(K)$ = number of samples for factor class K and N = total number of samples. The degree of departures of CF values from 1 indicates the level of response to that ecological factor. Values above 1 indicate a preference and values below 1 indicate a rejection.

A multivariate statistical approach was employed to individuate ecological species groups, by classifying and ordering the ecological profiles for each factor. Classification was performed by the minimum increase of sum of square agglomeration based on the chord distance (Orloci 1978), ordination by the correspondence analysis (Benzecri 1973). For computations the package SYNTAX 5.0 (Podani 1993) was used.

The local indicator species were detected applying the Kolmogorov-Smirnov goodness-of-fit testing to the ecological profiles in order to investigate whether the observed distribution of a species within the classes of each factor showed significant departures from the distribution expected under the null hypothesis of uniformity.

The nomenclature of species follows Pignatti (1982) for vascular plants, with the exception of *Carex nigra* (L.) Richard (Chater 1980), Corley *et al.* (1981) and Corley & Crundwell (1991) for bryophytes.

4. RESULTS

The plot of factor entropies against mean mutual species-factor information (Fig. 2) points up that each ecological factor appears adequately sampled and it plays a discriminant role on species distribution. In particular, altitude and electrical conductivity appear as more efficient than pH for predicting species distribution.

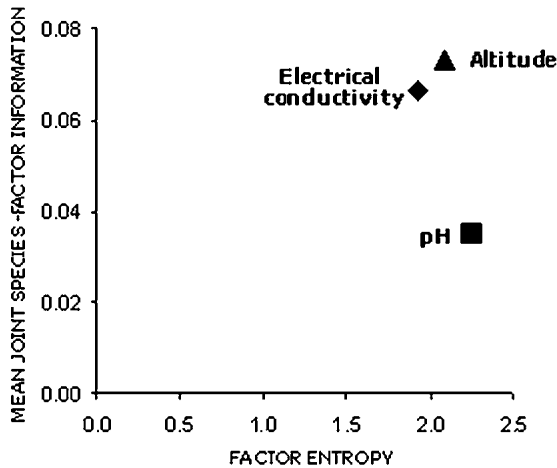


Fig. 2. Plot of mean joint species-factor information against entropy.

The ecological profiles of 18 species, giving a readily interpretable information about ecological amplitude of species and allowing to underscore their preferences for the factor, are reported in figure 3.

The ordination of ecological species groups, obtained for each factor by the classification of the ecological profiles, allows to point out some groups of species gravitating around a particular factor class and arranged along the first two ordination axes according to the gradients of the factors (Fig. 4).

For altitude three ecological species groups are clearly separated in the graph (Fig. 4a). The group composed by *Carex rostrata*, *C. tumidicarpa*, *Juncus alpino-articulatus*, *Eriophorum latifolium* and *Menyanthes trifoliata*, is centered around the lowest classes of the factor and it occurs preferentially at low altitudes, below 1400 m. A second species group numerically richer and composed by *Sphagnum capillifolium*, *S. palustre*, *S. subsecundum*, *Eriophorum angustifolium*, *Carex irrigua*, *Campylium stellatum* and *Trichophorum alpinum*, shows preferences for altitudes between 1400 and 1600 m. A third group of species, consisting of *Warnstorfia exannulata*, *Juncus filiformis*, *Viola palustris*, *Carex stellulata*, *C. nigra* and *Parnassia palustris* occurs preferentially above 1600 m.

Also for pH it is possible to point up three species groups (Fig. 4b). The first group, formed by *Sphagnum capillifolium* and *S. palustre*, shows high preferences for the lowest classes of the factor, under a pH value of 5.70. A second group of species, composed by the core-bulk of the species occurring in the northern Apennine wetlands, occurs preferentially at pH values ranging from 5.10 to 6.30. Furthermore, a third species group, consisting of *Eriophorum latifolium*, *Campylium stellatum*, *Carex tumidicarpa*, *Juncus alpino-articulatus*, *Parnassia palustris* and *Viola palustris*, show preferences for pH values above 6.30.

Only two species groups can be clearly separated along a gradient of electrical conductivity (Fig. 4c). The first one, composed by *Sphagnum capillifolium*, *S. palustre*, *S. subsecundum*, *Eriophorum angustifolium*, *Menyanthes trifoliata* and *Trichophorum alpinum* is linked to values of electrical conductivity below $120 \mu\text{S cm}^{-1}$. *Sphagnum capillifolium* and *Menyanthes trifoliata* are centered in the second class (between $40\text{--}80 \mu\text{S cm}^{-1}$), whereas *Sphagnum palustre*, *S. subsecundum*, *Eriophorum angustifolium* and *Trichophorum alpinum* occur preferentially between 40 and $120 \mu\text{S cm}^{-1}$. The second group of species, composed by *Carex nigra*, *C. rostrata*, *C. stellulata*, *C. irrigua*, *C. tumidicarpa*, *Parnassia palustris*, *Eriophorum latifolium*, *Juncus alpino-articulatus*, *Campylium stellatum* and *Viola palustris*, occurs preferentially above $80 \mu\text{S cm}^{-1}$. Among these species, a subgroup, composed by *Parnassia palustris*, *Eriophorum latifolium*, *Carex tumidicarpa*, *Juncus alpino-articulatus*, *Campylium stellatum* and *Viola palustris*, can be separated. This subgroup is centered around the highest class of the factor, above $120 \mu\text{S cm}^{-1}$. Furthermore, *Warnstorfia exannulata* and *Juncus filiformis* were not included within a specific group, for having a bimodal distribution with two different peaks at the extreme classes (Fig. 3).

The results of Kolmogorov-Smirnov test show that some ecological profiles deviate significantly from uniformity. Observed frequencies are significantly different ($p < 0.05$) from corresponding expected frequencies for 7 species in the ecological profiles concerning altitude, for 4 species in those concerning electrical conductivity and for 1 species only in those concerning pH (Fig. 3).

Concerning altitude, three species (*Carex rostrata*, *Juncus alpino-articulatus* and *Eriophorum latifolium*), mostly occurring below 1400 m, form a thermophilous species group; whereas the species mostly sampled above 1600 m (*Carex nigra*, *Juncus filiformis* and *Warnstorfia exannulata*) are clearly cryophilous. *Eriophorum angustifolium*, mostly occurring between 1400 and 1600 m, is significantly correlated to intermediate temperature conditions.

Campylium stellatum, *Carex tumidicarpa*, *Eriophorum latifolium* and *Juncus alpino-articulatus*, mostly occurring at values of electrical conductivity above $80 \mu\text{S cm}^{-1}$, can be regarded as good indicators for the highest trophic levels occurring in the peatlands of the northern Apennines. In the ecological profiles concerning pH, only the observed frequencies of *Sphagnum capillifolium* deviate significantly from uniformity; therefore, this species can be considered a good indicator for pH values lower than 5.70.

5. DISCUSSION

Ten species (7 vascular plants and 3 bryophytes) resulted mostly predictive with respect to the variation of habitat factors in the wetlands of the northern Apennines.

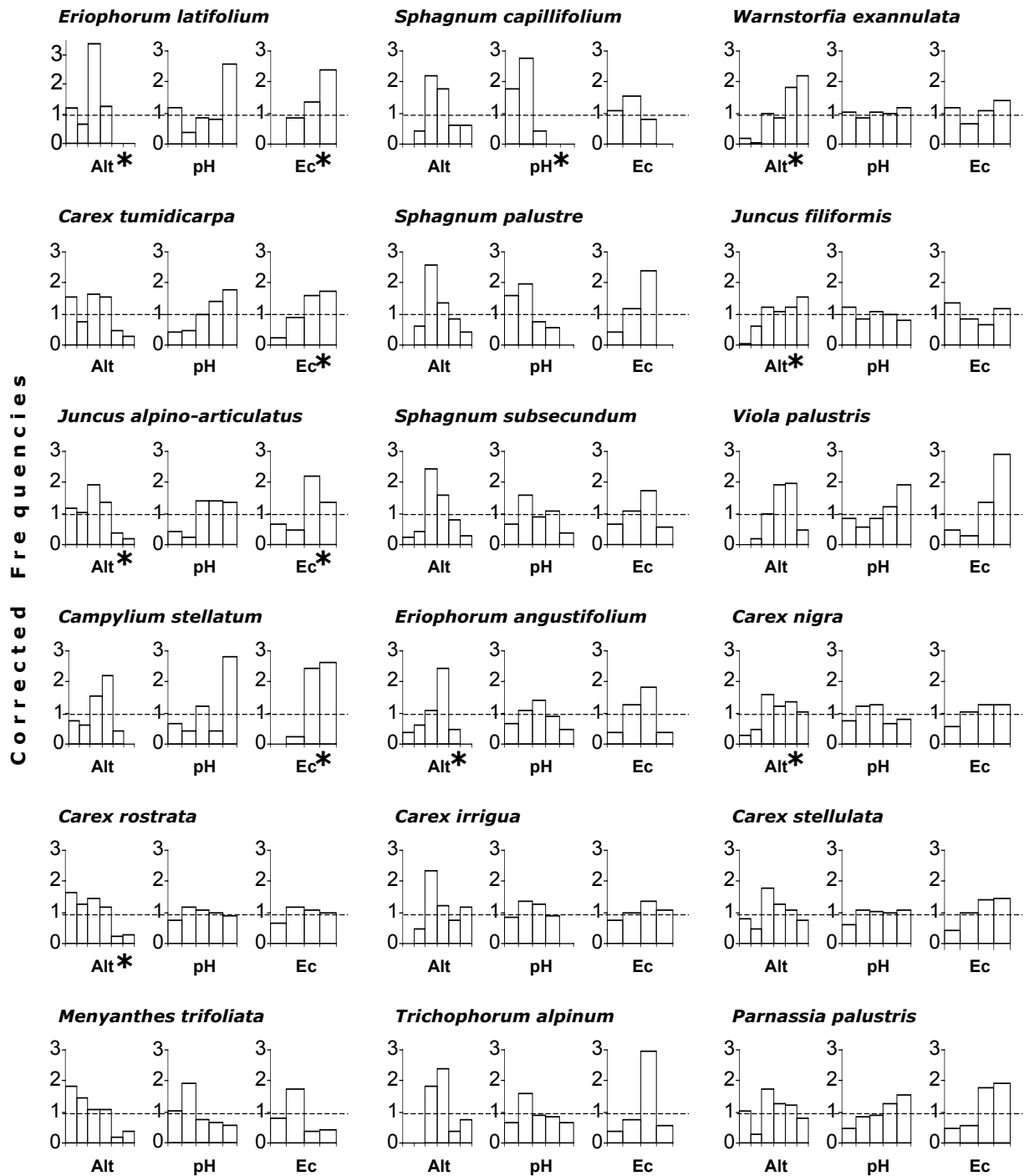


Fig. 3. Ecological profiles with respect to altitude, pH and conductivity. Each factor was divided into a different number of classes of equal value as reported in table 1. Asterisks indicate significantly non-uniform distribution ($p < 0.05$) with respect to those factors. Profile values of 1 indicate uniform distribution; values greater than 1 indicate preference.

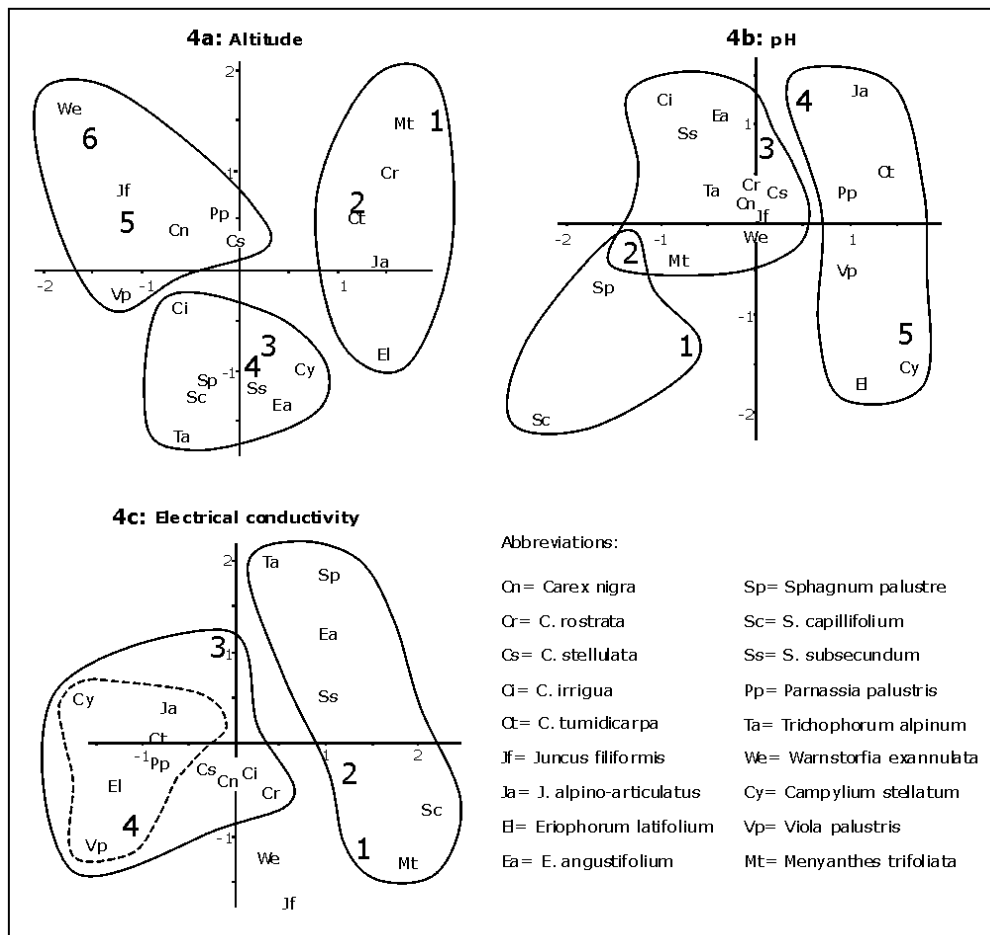


Fig. 4. Species groups gravitating around a particular factor class (bold numbers) and arranged along the first two ordination axes according to the gradients of the factors. Each ecological factor was subdivided into different numbers of classes of equal amplitude as reported in table 1.

These wetlands are spread within a relatively broad altitudinal range (from 1100 to 1800 m) and, therefore, the number of species, whose distribution is significantly correlated with altitude, is particularly high.

On the contrary, only one species resulted significantly correlated with pH variation. In the northern Apennine wetlands, the variation range of this parameter is, in fact, markedly narrower with respect to that of the altitude. That is due to two fundamental reasons: i) in the summits of the northern Apennines geological substratum consists of lime-poor rocks; ii) ombrotrophic mires (bogs) lack at all in this area and, moreover, among minerotrophic mires (fens), the greatest number is represented by moderate-rich fens.

For the electrical conductivity, the number of indicator species (4) is intermediate. The significant correlation between the distribution of these species and the highest classes of this parameter is not a surprising result. *Eriophorum latifolium*, *Campylium stellatum* and *Juncus alpino-articulatus* occur, in fact, very frequently in the Alps within rich calcareous fens (Steiner 1992;

Gerdol 1994; Gerdol & Tomaselli 1997). On the other hand, rich fens lack at all in the northern Apennines (Gerdol & Tomaselli 1993) and, consequently, the occurrence of this species presumably reflects small-scale nutrient distribution patterns occurring in some mires.

Vegetation patterns in boreal and north-temperate peatlands are strongly affected by a "poor-rich in nutrients" gradient (Sjörs 1948). The poor-rich direction of variation in vegetation was paralleled by a general increase in ion concentration in peatland water (Du Rietz 1949; Witting 1949; Gorham, 1956; Jeglum 1971; Vitt & Chee 1990). Calcium, magnesium and sodium are most responsible for this increase, reflected by electrical conductivity measures.

The occurrence of rich-fen species within the acidophytic mires of the northern Apennines is presumably determined by small scale poor-rich gradients, linked to surface microtopography.

The second aim of this work was to verify shifts in the ecological optima of wetland species occurring in the northern Apennines. No data are presently available

for electrical conductivity, but for pH and altitude it is possible to verify some ecological shifting, comparing our profiles with those reported by Gerdol & Tomaselli from the Dolomites (1997).

Eriophorum angustifolium, *E. latifolium* and *Juncus alpino-articulatus* occur in the northern Apennines at lower altitudes than in the Alps. Concerning pH, four species show a certain degree of shifting in their ecological profiles. In the northern Apennines, the profiles of *Menyanthes trifoliata* and *Trichophorum alpinum* are shifted towards lower values, corresponding to more acidic habitats, while those of *Sphagnum capillifolium* and *Viola palustris* show an opposite behaviour.

The ecological shifting in altitude and towards more acidic habitats can be explained by the absence in the northern Apennines of suitable habitats for these species (mires above 1800 m and rich fens). Also for *Sphagnum capillifolium* the shift in the ecological optimum is presumably due to the absence of suitable habitats, such as ombrotrophic mires and to the rarity of intermediate mires with *Sphagnum* hummocks in the northern Apennines. The shift concerning pH range of *Viola palustris* can be hardly explained. A first hypothesis could be the occurrence, at the southern distributional border of this species, of an ecotype having different ecological requirements. According a second hypothesis, the ecological profile could be conditioned by modifications in the competitive equilibria with other species.

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