Ecology of some mire and bog plant communities in the Western Italian Alps

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ABSTRACT

During a mire vegetation study, conducted mainly in the subalpine-alpine sector of the Western Italian Alps, the ecology of several plant communities and numerous moss species of this kind of vegetation was evaluated. The study area covered the Piedmontese sector of the Graian Alps, the eastern sector of the Aosta Valley as well as certain localities of the Pennine Alps, the Canavese district and the Maritime Alps. They have a rocky substratum representative of the various regional lithologies and include the main sectors characterised by the highest precipitation. Three hundred and twenty two relevées were made using the phytosociological method and the pH and the conductivity of the water table and its depth were measured directly. Cluster Analysis allowed a classification of the samples and the identification of various groups of plant communities. Ordination performed by DCA and CCA allowed us to identify the ecological features of the various plant communities by using the values of the main environmental parameters, measured directly in the field, and certain climatic parameters (altitude and mean annual precipitation) available. The use of climatic parameters is an important result for identifying communities which show greater oceanicity, something that is underlined also by the presence of indicator species such as Sphagnum papillosum *and* S. subnitens*. Furthermore the communities are arranged in a "poor-rich" gradient, and are also profoundly influenced by depth to water table which is inversely correlated to the pH. Therefore we find certain kinds of communities all with a very low water table and which are little affected by its chemistry. Other groups share the fact that the water table is outcropping or near the surface and are distinguishable for their pH values and conductivity. We discuss the different response of the bryophytes and vascular plants of these communities to the environmental parameters considered, in light of their anatomic and functional differences. Bryophytes are more sensitive to environmental and climatic parameters whilst vascular plants are mostly ubiquitous in the relevées with a greater ecological plasticity.*

Key words: Sphagnum*, peatlands, mire vegetation, brown-mosses, water chemistry, oceanicity-continentality gradient*

1. INTRODUCTION

Water chemistry and depth to the water table are important for determining ecological niches of plant species present in mires (Andrus *et al*. 1983; Bragazza 1999, 1997; Gerdol 1995; Malmer 1993, 1986; Okland 1990; Duenhofen & Zechmeister 2000). Higher plants, as a result of their root anatomy, the positions of the meristem tips and their resistance to acidic environments, often have a broader ecological niche than bryophytes which are more sensitive to variations in these parameters (Malmer 1994).

Sphagna, which are a major feature of mire plant communities along with other bryophytes, are linked not only to water chemistry and to the depth to the water table but also to the oceanicity-continentality climatic gradient (Gignac 1993; Gignac et al. 1991; Gignac & Vitt 1990).

Numerous works have been recently published on the Southern Italian Alps which have studied plant communities with reference to the various gradients for water table depths, pH variation and the availability of nutrients, and often considering the hydrology of the wetlands (Gerdol 1990, 1995; Bragazza & Gerdol 1996, 1999; Bragazza 1997, 1999; Zavagno *et al*. 2001).

In the Western Italian Alps these plant communities have been little studied and only considering purely phytosociological aspects and therefore require further study (Montacchini 1986-87; Montacchini *et al*. 1982; Rey 1990; Miserere *et al*. 1997/98; Miserere *et al*. 1998). As part of a doctorate thesis a study was made on mire vegetation which has allowed an evaluation of the ecology of certain plant communities and of numerous characteristic moss species on the basis of the chemical-physical data of the water table as well as climatic ones (Miserere 2000; Miserere *et al*. 2002).

2. METHODS

The study areas are located in the Piedmontese sector of the Graian Alps (Lanzo Valleys and Locana Valley), in the Eastern part of the Aosta Valley (Champorcher, Champdepraz and Gressoney Valleys) as well as some other localities of the Pennine Alps (Sesia Valley) and the Canavese district. Furthermore certain areas of the Biella district and, much further south, of the Maritime Alps (Pesio Valley) were considered (Fig. 1). In the Western Italian Alps, the study areas have a rocky substratum which is representative of the various lithologies, and furthermore, are the main sectors with high precipitation levels.

Three hundred and twenty two relevées were taken using the phytosociological method, conducting for each of them direct measurements of the main environmental parameters. The measurement of the pH and the

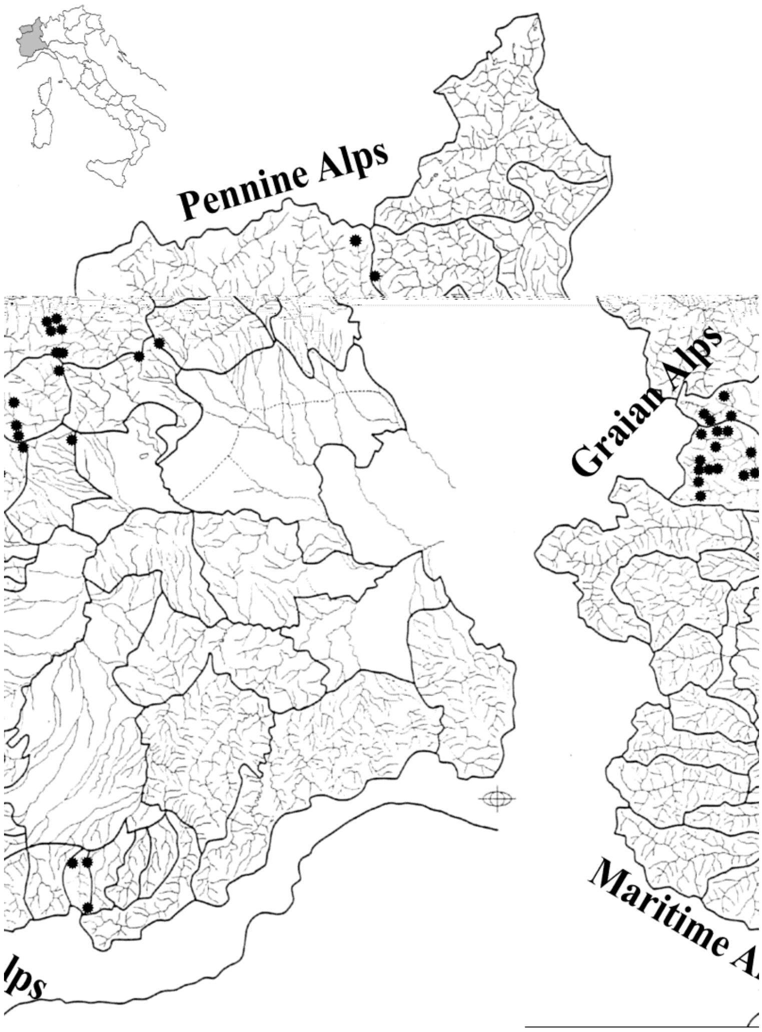


Fig. 1. Distribution of the localities where relevées were made in the Western Italian Alps.

conductivity of the water table were made in the field, using pH-meters and portable conductivity meters (WTW) equipped with thermo compensated probes, as well as the measurement of the depth to the water table. The depth to the water table was assessed by using a steel screw probe, by estimating to what depth from the surface there remained traces of wet peat in the threads. As far as climatic parameters are concerned, we considered literature data, the mean annual precipitation (Biancotti *et al*. 1998) and altitude for its correlation with mean annual temperatures, which are not all available for the sampling locations considered.

The matrix of the data, obtained with the cover values of the species has been analysed statistically, with the Cluster Analysis (CA). Thus, by using average linkage method (UPGMA) and the "chord distance" as an algorithm of distance, has allowed a classification of the relevées and the identification of the plant communities (Orloci 1978; Podani 1994). The species mean values of the main groups obtained from the first analysis have been classified with the same method a second time. This second cluster shows the high hierarchical levels of the dendrogram on 322 relevées in a more simple way (Fig. 2).

Later, to determine the relationships between the identified plant communities and the environmental parameters, and hence to identify the ecological gradients mainly responsible for the kinds of vegetation observed, we performed non constrained ordinations with the use of DCA and constrained ordinations employing canonical correspondence analysis (CCA) (Ter Braak & Verdonschot 1995; Ter Braak 1996, Ter Braak & Šmilauer 1998), including the use of environmental and climatic parameters.

3. RESULTS

The CA (Fig. 2), has placed the relevées in 3 main groups. Further subdivisions within these 3 groups represent different communities (shown by various symbols in Fig. 2 and in Tab. 1) and are reported with the

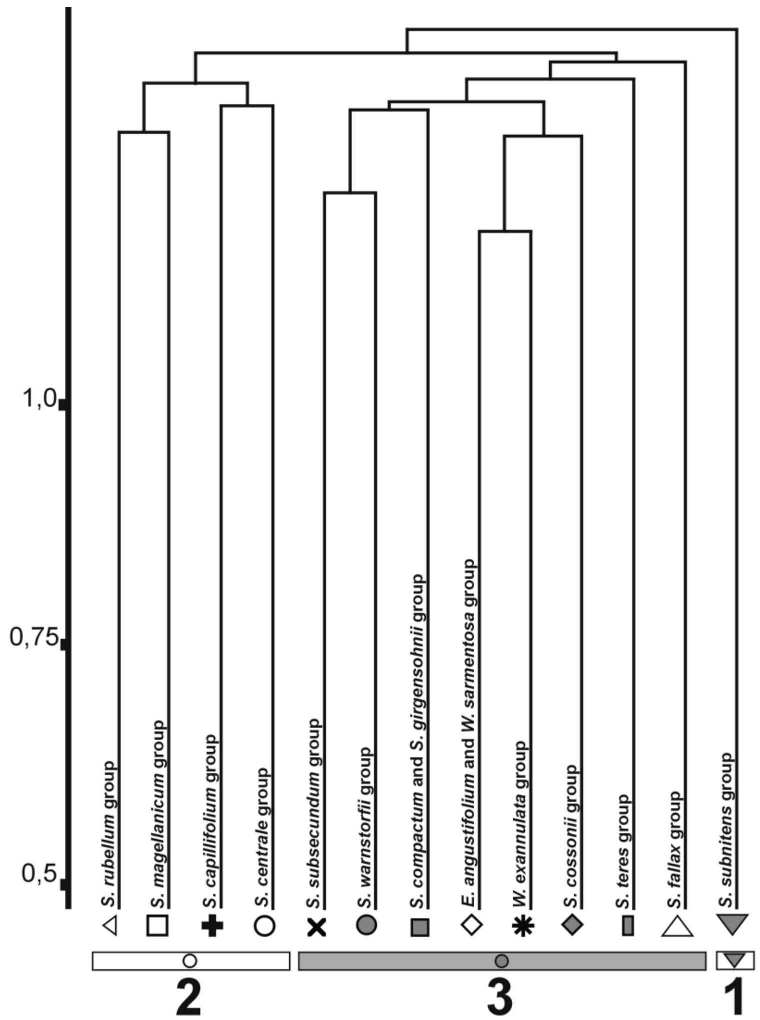


Fig. 2. Cluster Analysis on the mean species composition values in each group, with the main groups of relevées identified by a first CA (not shown for printing reasons).

same symbols in the analyses performed with DCA and CCA. The ecological characteristics of these communities as obtained by CCA are visible in figures 5, 6 and 7.

The first group consists of a limited number of relevées (18) and corresponds to plant communities characterised by *Sphagnum* species and in particular by *Sphagnum subnitens* and *Sphagnum papillosum* together with numerous species typical of the plant communities of bogs. They favour low pH and conductivity values with climatic features typical of lower altitudes and particularly of high mean annual precipitation. In figure 2 this community is marked with number 1 and by the grey triangle symbol.

The second group of relevées consists of a far higher number of samplings (142) and corresponds to plant communities characterised by numerous species of *Sphagnum* which form typical hummocks in bogs, raised above the water table. Phytosociologically, they belong to the class *Oxycocco-Sphagnetea* Br.-Bl. et R. Tx. ex Westhoff *et al*. 1946, they prefer low pH and conductivity values and compared to group 1 they are generally present at higher altitudes. They are marked in figures 2, 3 and 5 by the number 2 and by the white circle symbol.

The last group is made up by the highest number of relevées (162) and corresponds to plant communities of minerotrophic mires characterised by *Sphagnum* species and mosses which form carpets which are little raised above the water table and in some cases they are floating or even submerged. They all belong phytosociologically to the class *Scheuchzerio-Caricetea fuscae* R. Tx. 1937. One may identify, within the CA subdivisions of this large group, communities with different characteristics for pH and conductivity values which are higher than those of group 2. They are marked in figures 2, 3 and 5 with the number 3 and by the grey circle symbol.

4. DISCUSSION

DCA provides an ordination which reflects the differences in specific composition of the relevées. Although there is a gradual transition in the central part of

Tab. 1. The parameter measurements indicate mean values and standard deviations shown in brackets.

Symbol	Dominant species	Number of relevées	pH	Conductivity (μS cm^{-1})	Depth to water table (cm)	Other frequent and dominant species
◁	*Sphagnum rubellum*	44	4.34 (±0.58)	53.48 (±17.00)	18.11 (±9.38)	*Carex nigra, Nardus stricta, Viola palustris, Vaccinium uliginosum subsp. mycrophyllum, Potentilla erecta, Leontodon helveticus, Carex echinata, Vaccinium vitis-idaea, Aulacomnium palustre, Molinia caerulea, Carex pauciflora, Sphagnum capillifolium* var. *capillifolium, Sphagnum angustifolium*
□	*Sphagnum magellanicum*	12	4.61 (±0.44)	55.38 (±18.79)	28.50 (±10.98)	*Carex nigra, Straminergon stramineum, Nardus stricta, Viola palustris, Vaccinium vitis-idaea, Potentilla erecta, Scirpus caespitosus*
▽	*Sphagnum subnitens, Sphagnum papillosum*	18	4.43 (±0.61)	53.17 (±17.00)	20.29 (±10.22)	*Potentilla erecta, Molinia caerulea, Drosera rotundifolia, Scirpus sylvaticus, Calluna vulgaris,*
✚	*Sphagnum capillifolium*	70	4.44 (±0.65)	61.53 (±29.21)	18.29 (±10.10)	*Nardus stricta, Carex nigra, Vaccinium uliginosum* subsp. *mycrophyllum, Carex echinata, Potentilla erecta, Aulacomnium palustre, Viola palustris, Eriophorum angustifolium, Scirpus caespitosus, Calluna vulgaris, Molinia caerulea, Straminergon stramineum, Vaccinium vitis-idaea*
○	*Sphagnum centrale*	16	5.05 (±0.43)	72.50 (±31.54)	17.06 (±9.06)	*Carex nigra, Viola palustris, Luzula sudetica, Potentilla erecta, Carex echinata, Anthoxanthum odoratum, Festuca rubra* subsp. *rubra*
✖	*Sphagnum subsecundum*	34	4.89 (±0.54)	45.81 (±20.58)	12.88 (±9.40)	*Carex echinata, Scirpus caespitosus, Carex nigra, Viola palustris, Warnstorfia exannulata, Eriophorum angustifolium, Calliergon stramineum, Carex rostrata, Drosera rotundifolia*
▣	*Sphagnum compactum, Sphagnum girgensohnii*	9	4.69 (±0.37)	50.08 (±23.68)	8.89 (±4.17)	*Carex nigra, Nardus stricta, Carex echinata, Calliergon stramineum, Viola palustris*
△	*Sphagnum fallax*	12	5.02 (±0.55)	43.84 (±14.84)	13.00 (±6.56)	*Carex nigra, Carex echinata, Carex rostrata, Equisetum palustre*
▮	*Sphagnum teres*	23	5.19 (±0.50)	80.31 (±39.81)	12.5 (±5.06)	*Carex nigra, Viola palustris, Potentilla erecta, Carex echinata, Molinia caerulea, Festuca rubra* subsp. *rubra, Nardus stricta*
●	*Sphagnum warnstorfii*	13	5.40 (±0.50)	75.72 (±27.29)	12.31 (±5.25)	*Carex nigra, Viola palustris, Aulacomnium palustre, Straminergon stramineum, Parnassia palustris, Sphagnum subsecundum*
◇	*Eriophorum angustifolium, Warnstorfia sarmentosa*	26	5.32 (±0.51)	61.03 (±31.52)	3.10 (±4.87)	*Scirpus caespitosus, Carex nigra, Carex echinata, Odontoschisma elongatum*
✱	*Warnstorfia exannulata*	25	5.26 (±0.46)	62.87 (±57.60)	1.52 (±2.79)	*Carex nigra, Carex echinata, Viola palustris, Eriophorum angustifolium*
◆	*Scorpidium cossonii, Carex lepidocarpa*	20	6.02 (±0.44)	140.76 (±66.49)	0.38 (±1.39)	*Carex nigra, Bryum pseudotriquetrum, Campylium stellatum, Equisetum palustre, Eriophorum latifolium*

the diagram (Fig. 3), the three CA groups assume distinctive positions in ordination space. The group characterised by the predominance of *Sphagnum papillosum* and *S. subnitens* is clearly distinguishable from the other two along the first axis for its particular floristic composition. Along the second axis the distinction between the communities of groups 1 and 2 and group 3 can be observed. The distinction between the CA subgroups in the DCA ordination diagram (Fig. 4) is not always clear and there are ample overlaps, especially in the central transition area between group 2 and 3 communities dominated by *Sphagnum centrale*, *S. warnstorfi* and *S. subsecundum*. can be observed. In the more heterogeneous third group some subgroups are clearly distinguishable (*Sphagnum fallax*, *Warnstorfia exannulata*, *Scorpidium cossonii-Carex lepidocarpa*) whilst others show areas of different gravitation but with ample overlaps.

The CCA results which include the environmental and climatic parameters (as well as their specific composition) show how the community characterised by *Sphagnum subnitens* and *S. papillosum* (relevée group 1) here too appears isolated and clearly distinct along

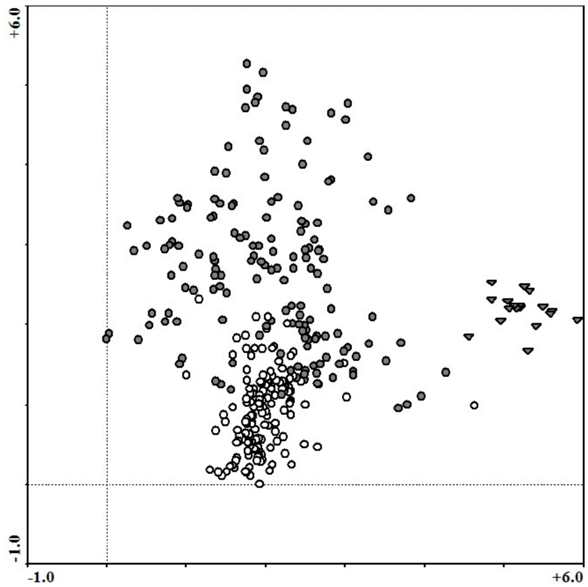


Fig. 3. DCA diagram which illustrates the arrangement of the three main groups obtained from the CA.

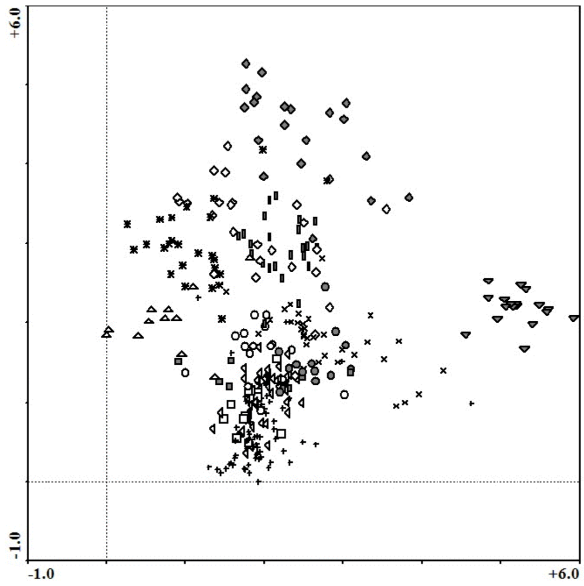


Fig. 4. DCA diagram which illustrates the arrangement of all the main groups obtained from the CA.

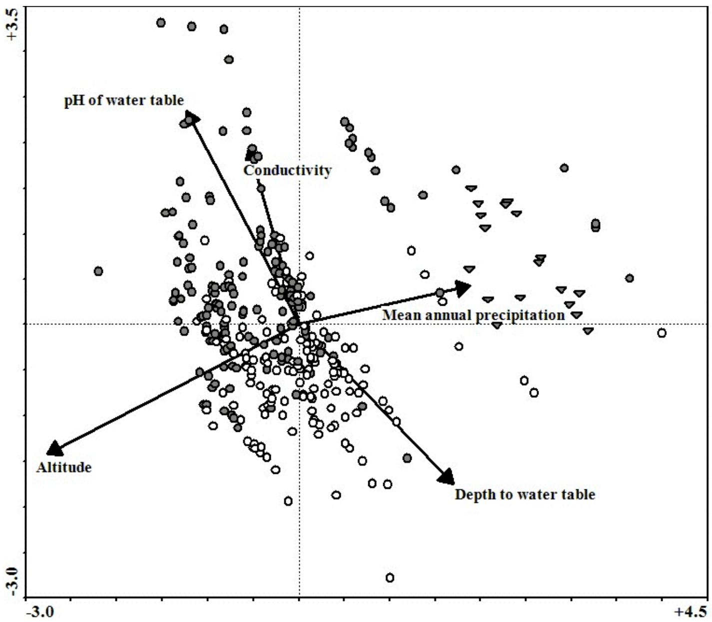


Fig. 5. Correlation biplot based on CCA. Axes 1 and 2 (eigenvalues respectively 0.51 and 0.46; the sum of all canonical eigenvalues is 1.53) explain the 4.9% of cumulative percentage variance in species data and the 61.8% of cumulative percentage variance of the species-environment relationships; both are statistically significant (Monte Carlo Permutation Test P = 0.005). The first axis is closely inversely correlated to "altitude" and directly to the "mean annual precipitation" (inter set correlations of "altitude" to axis 1 = -0.75 and "mean annual precipitation" with axis 1 = 0.51).

the first axis (Fig. 5). This axis appears clearly influenced by altitude and mean annual precipitation. This differentiation on a climatic basis is also reported in North America especially for *Sphagnum papillosum* where the factors limiting distribution seem to be extreme climatic conditions (Gignac 1993). Actually the *Sphagnum subnitens* and *S. papillosum* group consists of a number of relevées made in the Pesio and Oropa Valleys, which have the lowest altitudes and the highest mean precipitation values. Compared to the other relevées there are thus certainly less extreme climatic conditions. On the other hand, the separation between groups 2 and 3 along the second axis shows a subdivision along a "poor-rich" gradient which is clearly affected by the depth to the water table, inversely correlated to pH and to conductivity. Several similar communities are found which have in common the considerable depth to the water table (CA group 2). Group 3

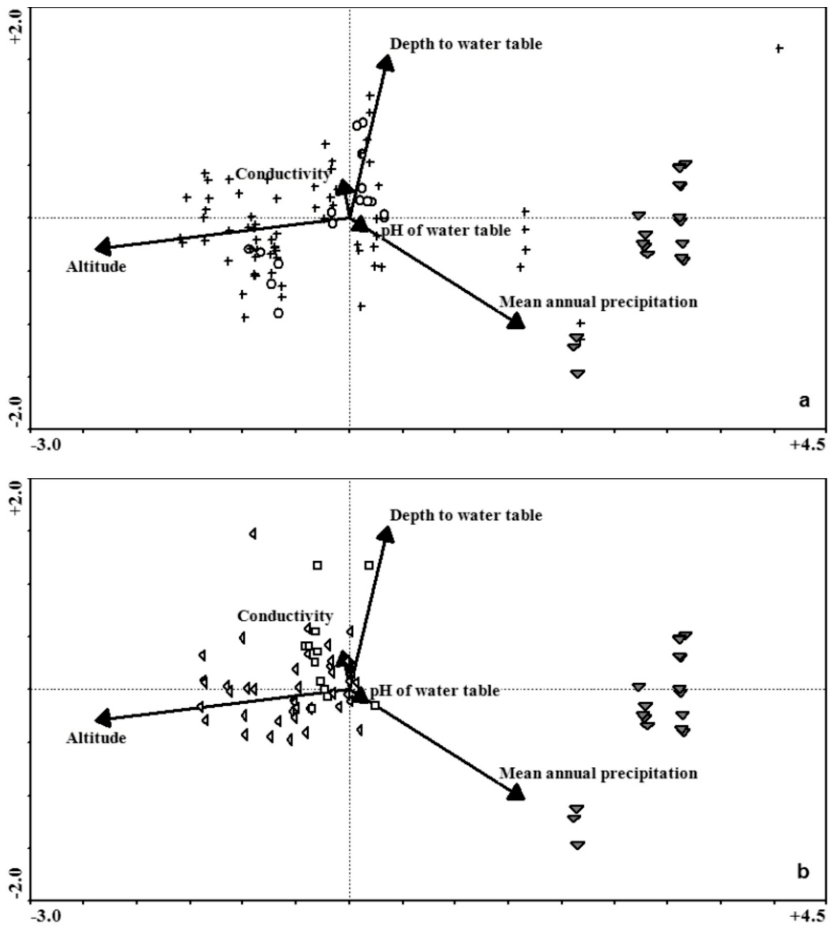


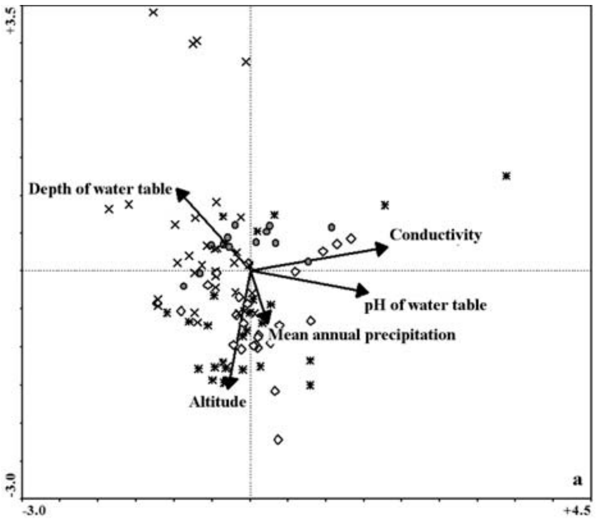
Fig. 6. Partial CCA of relevées of groups 1 and 2 of CA. Arrangement in ordination space of all the groups isolated by CA. The canonical ordination axes 1 and 2 (eigenvalues of 0.60 and 0.18 respectively) explain the 7.6% of cumulative percentage variance in species data and the 72.6% of the species-environment relationships; both are statistically significant (Monte Carlo Permutation Test P = 0.005). The parameters "altitude" and "mean annual precipitation" appear as closely correlated to axis 1 and inversely correlated to one another (correlations to axis 1 –0.88 and 0.60 respectively).

distinguishes itself, although some relevées have intermediate characteristics, for the proximity of the water table to the surface, which in some cases outcrops.

On the basis of the environmental and climatic parameters shown in figure 5, ordinations with separate CCA were performed, only on relevées of CA groups 2 and 3 (Figs 6 and 7). Figures 6 and 7 which show the results of these computations were further doubled (a and b) for an enhanced display of the arrangement of the identified communities.

As far as the ombrotrophic mires of group 2 are concerned there clearly emerges the poor significance of the water table pH and conductivity parameters in the ordination space (Figs 6a and 6b). These graphic data are confirmed by the forward selection values where the conditional effects are significantly low (water table pH $\lambda = 0.11$ and $p = 0.005$; conductivity $\lambda = 0.08$ and $p = 0.105$), and from the values and standard deviations summarised in table 1. The table shows that the group characterised by *Sphagnum subnitens* and *papillosum* maintains its differences concerning the climatic parameters whilst all the other relevées show a general overlapping. The *Sphagnum* species which characterise these relevées are *Sphagnum centrale*, *S. rubellum*, *S. magellanicum* and *S. capillifolium*. Considering that *S. magellanicum* has a considerable amplitude of climatic niche which has also been acknowledged in North America (Gignac 1993), together with *S. rubellum* and *S. centrale* in the studied zones it behaves very similarly to *S. capillifolium* which on the other hand in America is known for its preference of more continental and extreme climatic zones (Gignac 1993).

Whilst for *S. magellanicum* and *S. centrale* this trend is less evident, occupying a fairly central area from the axis, *S. rubellum* and *S. capillifolium* show similar climatic preferences which are clearly distinguished from those of *S. papillosum*. Certainly the climatic preferences of *S. rubellum* merit further study because they are discordant with those of North America where this species shows oceanic climatic preferences very similar to those of *S. papillosum* (Gignac 1993).



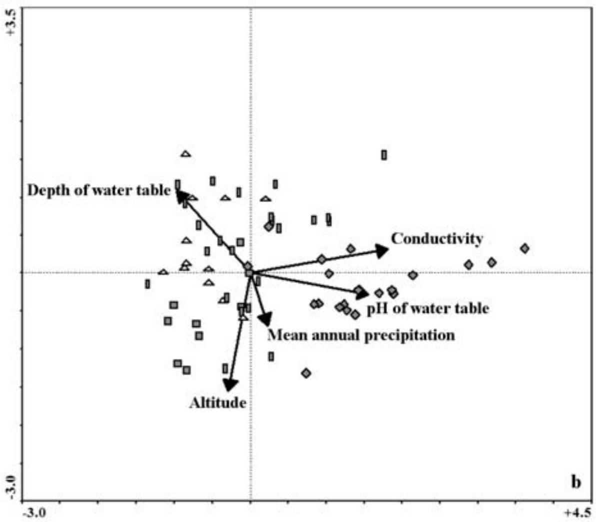


Fig. 7. Partial CCA of group 3 relevées of CA. Arrangement in ordination spaced of all the groups isolated by CA. The canonical ordination axes 1 and 2 (eignevalues of 0.45 and 0.42 respectively) explain the 6% of cumulative percentage variance in species data and the 62.2% of the species-environment relationships; both are statistically significant (Monte Carlo Permutation Test P = 0.005). The parameters "altitude" and "mean annual precipitation" in this case appear as little correlated to axis 1 and inversely correlated to one another (correlations to axis 1 –0.12 and 0.09 respectively). On the other hand the conductivity and the pH of the water table are closely correlated to axis 1 and as well as being correlated to one another (correlations to axis 1 0.77 and 0.66 respectively).

As far as the depth and chemistry of the water table are concerned these species are also those which show greater competition and niche amplitude with inevitable overlaps (Okland 1990; Andrus 1986; Bragazza 1997; Gerdol 1995). The ecological confirmation of this behaviour, found in the ordination from the scarce significance of the environmental parameters, is also provided by the frequent and dominant species of vascular plants found in the communities (see Tab. 1). Because of their root anatomy, the position of their meristem tips and their tolerance of acidic habitats they often have a wider ecological niche (Malmer *et al*. 1994). The confirmation is provided by the numerous species which are common and very often present with similar and considerable cover values in many of the communities identified in both groups 2 and 3 of the CA, such as *Carex nigra*, *Carex echinata*, *Viola palustris*, *Potentilla erecta*, *Nardus stricta* and *Eriophorum angustifolium*.

Thus the bryophytic component becomes the discriminating one, because it is more sensitive to the varying depth to the water table and its water chemistry. Therefore, inevitably, this component has a more restricted ecological niche, as has often been stressed in the literature (Malmer 1986, 1993; Bragazza 1999; Andrus *et al*. 1983). In vascular plants too, when the ecological niche of some species is more restricted, such species are to a greater extent characteristic of one of the communities as is shown by the statistical analysis, this is the case with *Carex pauciflora* and *Drosera rotundifolia*.

Furthermore, from a phytosociological point of view the relevées of group 2, taken as a whole, may be attributed to different variants of the same association *Sphagnum medii* Kästner et Flößner 1933 (Steiner 1993; Gerdol & Tomaselli 1997).

In the behaviour of the CA group 3 relevées it is clearly visible how conductivity and the pH of the water table acquire a greater significance and one that is correlated to the first axis (see Figs 7a and 7b). The forward selection values show how the conditional effects have a greater significance especially for conductivity (water table pH λ = 0.15 and p = 0.005; conductivity λ = 0.41 and p = 0.005). The depth to the water table is also inversely correlated in this community to the preceding environmental parameters. It contributes considerably to distinguishing *Sphagnum* carpet communities just above the water table and with lower pH and conductivity values within group 3. These communities are characterised by the presence of *Sphagnum subsecundum*, *S. teres*, *S. warnstorfii*, *S. compactum* and *S. girgensohnii*. There is a slight difference between them, as confirmed by the average values reported in table 1, of the *S. teres* and *S. warnstorfii* communities which show slightly higher water table conductivity values. On the other hand, the other communities characterised by the presence of brown mosses, how *Warnstorfia exannulata*, *Warnstorfia sarmentosa* - *Eriophorum angustifolium* and *Scorpidium cossonii* - *Carex lepidocarpa*, are characterised by outcropping surface water and high conductivity and pH values. These communities show a high affinity in the CA on the species composition too where they form a single cluster, while the precedent communities with *Sphagnum* are grouped separately. Differentiation on the basis of conductivity is present in communities which are characterised by *Warnstorfia sarmentosa* - *Eriophorum angustifolium*, *Warnstorfia exannulata* which show very low average values (61.03

μS cm^{-1}, 62.87 μS cm^{-1}) compared to communities characterised by the presence of *Scorpidium cossonii* where the water was much richer in dissolved ions (140.76 μS cm^{-1}). Moreover, these communities seem to distinguish themselves from others along the second axis which is heavily conditioned by altitude. The communities characterised by *Warnstorfia sarmentosa* - *Eriophorum angustifolium*, *Sphagnum compactum* - *Sphagnum girgensohnii*, and *Warnstorfia exannulata* seem to prefer, compared to other relevées of group 3, more extreme climatic conditions dictated by the higher altitude.

The communities with *S. teres* and *S. fallax* distinguish in the CA (Fig. 2) from the other communities of the group 3 according to the species composition and they form well delimited groups in the DCA (Fig. 4). The communities with *S. teres* show a particular position in the CCA (Fig. 7) where they seem to prefer higher position to the water table and higher water table conductivity values. The conductivity is an important discriminator factor because these communities grow mainly on calcareous or basic substrate (serpentine and calcschist rocks). The communities with *S. fallax* are more separated from the others of the group 3 in the CA and in the DCA. The reason could be attributed to lower water table pH and conductivity values as shown the CCA (Fig. 7) and to particular ecological characteristics of *S. fallax*. It's a typical hollow species in pioneer situations and his important rule in the restoration of the lawns and bogs is known (Grosvernier *et al*. 1997).

5. CONCLUSIONS

As a result of ecological affinities in the different mire communities many species are frequently found with significant cover values, thereby sometimes making their classification and characterisation difficult. This is particularly true for some higher plants (e.g. *Carex nigra*, *Carex echinata*, *Viola palustris*, *Potentilla erecta*, *Nardus stricta* and *Eriophorum angustifolium*). Their lateral vegetative propagation, together with the limited size of the wetlands on the Italian side of the Western Alps, causes a reduction in the size of the individual homogeneous communities and favours an overlapping in the composition of species in the individual communities. Other species with a less extended ecological niche are useful in characterising the communities (e.g. *Carex paucilora*, *Carex lepidocarpa* and *Drosera rotundifolia*).

On the other hand bryophytes play an important role in identifying these plant communities, owing to both their high cover values and to their greater sensitivity to changes in water chemistry and to the depth to the water table.

As far as ecological distinctions are made, the climatic parameters such as altitude and mean annual precipitation play an important role in identifying certain plant communities typical of bogs (e.g. communities with *S. subnitens* and *S. papillosum*), together with distinctions conditioned by water table depth. The canonical ordination shows how, in the Western Italian Alps too, *Sphagnum papillosum* and *S. subnitens* show a climatic preference for areas with a greater oceanity, high precipitation and less severe temperatures. The importance of the climatic parameters in highlighting certain plant communities underlines the strict relationship that these environments have with climate and climatic changes (Gignac 1993; Gerdol *et al*. 1998). Hence in these mire plant communities, bryophytes and Sphagna can be used as climatic indicators as has already been done in North America (Gignac *et al*. 1998). A future continuous monitoring of the dynamics of these plant communities is important for verifying the effects of climatic changes especially on the Alps where wetlands cover very limited areas compared to in northern Europe.

On the other hand, poor or rich fen plant communities have a closer correlation to water table chemistry and show clear ecological differentiation in ordination space. The climatic parameters contribute marginally to the characterisation of the communities highlighting those that are able to resist more extreme temperature conditions. In this case too bryophytes such as *Warnstorfia exannulata*, *Warnstorfia sarmentosa*, *Scorpidium cossonii*, *Sphagnum subsecundum*, *S. teres*, *S. fallax* and *S. warnstorfii* play an important role in identifying communities.

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REFERENCES

Andrus, R.E. 1986. Some aspects of *Sphagnum* ecology. *Can. J. Bot*., 64: 416-426.

Andrus, R.E., D.J. Wagner & J.E. Titus. 1983. Vertical zonation of *Sphagnum* mosses along hummock-hollow gradients. *Can. J. Bot.*, 61: 3128-3139.

Biancotti, A., G. Bellardone, S. Bovo, B. Cagnazzi, L. Giacomelli & C. Marchisio. 1998. *Distribuzione regionale di piogge e temperature*. Regione Piemonte, Collana Studi Climatologici in Piemonte, 1. Regione Piemonte, Università degli Studi di Torino. Torino: 80 pp.

Bragazza, L. & R. Gerdol. 1996. Response surfaces of plant species along water-table depth and water pH gradients in a poor mire on the southern Alps. *Ann. Bot. Fenn*., 33: 11-20.

Bragazza, L. 1997. *Sphagnum* niche diversification in two oligotrophic mires in the Southern Alps of Italy. *The Bryologist*, 100(4): 507-515.

Bragazza, L. 1999. Spatial patterns of plant species in a poor mire on the Southern Alps (Italy). *Plant Biosystems*, 133(1): 83-92.

Bragazza, L. & R. Gerdol. 1999. Hydrology, groundwater chemistry, and peat chemistry in relation to habitat condition in a mire on the South-eastern Alps of Italy. *Plant Ecology*, 144: 243-256.

Duenhofen, A. & H. Zechmeister. 2000. *Sphagnum*-Zonation entlang von Wasserstands und Wasserchemiegradienten in zwei österreichischen Moorgebieten. *Herzogia,* 14: 157-169.

Gerdol, R. 1990. Vegetation patterns and nutrient status of two mixed mires in the southern Alps. *Journal of Vegetation Science*, 1: 663-668.
Gerdol, R. 1995. Community and species-performance patterns along an alpine poor-rich mire gradient. *Journal of Vegetation Science*, 6(2): 175-182.
Gerdol, R. & M. Tomaselli. 1997. *Vegetation of wetlands in the Dolomites*. Dissertationes Botanicae, J. Cramer Berlin-Stuttgart: 177 pp.
Gerdol, R., A. Bonora, R. Marchesini, R. Gualandri & S. Pancaldi. 1998. Growth response of *Sphagnum capillifolium* to nightime temperature and nutrient level: Mechanisms and implications for global change. *Arctic and Alpine Research*, 30(4): 388-395.
Gignac, L. D. 1993. Distribution of *Sphagnum* species, communities, and habitats in relation to climate. *Advances in Bryology*, 5: 187-222.
Gignac, L.D., B.J. Nicholson & S.E. Bayley. 1998. The utilization of Bryophytes in bioclimatic modeling: Predicted northward migration of mires in the Mackenzie River Basin, Canada, as a result of global warming. *The Bryologist*, 101(4): 572-587.
Grosvernier, P., Y. Matthey, & A. Buttler, 1997. Growth potential of three *Sphagnum* species in relation to water table level and peat properties with implications for their restoration in cut-over bogs. *Journal of Applied Ecology*, 34: 471-483.
Malmer, N. 1986. Vegetational gradients in relation to environmental conditions in nordwestern European mires. *Can. J. Bot*., 64: 375-383.
Malmer, N. 1993. Mineral nutrients in vegetation and surface layers of *Sphagnum*-dominated peat-forming systems. *Advances in Bryology*, 5: 223-248.
Malmer, N., B.M Svensson & B. Wallen. 1994. Interaction between *Sphagnum* mosses and field layer vascular plants in the development of peat-forming systems. *Folia Geobot. Phytotax*., Praha, 29: 483-496.
Miserere, L. 2000. *Studio della vegetazione delle torbiere subalpine e alpine delle Alpi Occidentali Italiane con particolare attenzione alle relazioni fra le coperture muscinali e la restante parte della vegetazione*. Ph.D. University Pavia: 111 pp.
Miserere, L., G. Buffa, A. Capo & G. Dal Vesco. 1997/98. Flora e vegetazione di due ambienti umidi dell'Alta Valle di Viù: Lac Falin e Sagna del Vallone (Val di Lanzo, Alpi Graie). *Allionia*, 35:117-136.

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Miserere, L., G. Buffa & F. Montacchini. 1998. La vegetazione delle zone umide della Valle Chalamy (Alpi Graie). *Rev. Valdôtaine d'Hist. Nat*., 52: 17-34.
Miserere, L., F. Montacchini & G. Buffa. 2002. Ecologia e distribuzione di alcuni muschi delle torbiere delle Alpi Occidentali Italiane. Atti del Convegno Nazionale "Botanica delle zone umide". Vercelli – Albano Vercellese 10-11 Novembre 2000. Mus. Reg. Sci. Nat. Torino, Suppl.: 293-310.
Montacchini, F., R. Caramiello Lomagno, G. Forneris & R. Piervittori. 1982. *Carta della Vegetazione della valle di Susa ed evidenziazione dell'influsso antropico*. C.N.R., Coll. Progr. Final. Promozione della qualità dell'ambiente, AQ/1/220, Torino: 114 pp.
Montacchini, F. 1986-87. Tipi di Vegetazione Naturali e Antropici sul Territorio Piemontese. *Annali dell'Accademia di agricoltura di Torino*, 79: 167-191.
Okland, R.H. 1990. A phytoecological study of the mire Northern Kisselbergmosen, SE Norway. II. Identification of gradients by detrended (canonical) correspondence analysis. *Nord. J. Bot*., 10: 79-108.
Orloci, L. 1978. *Multivariate Analysis in vegetation research*. 2nd edition. Dr W. Junk B. V., The Hague. 451 pp.
Podani, J. 1994. *Multivariate Data Analysis in Ecological and systematics. A methodological guide to the SYN_TAX 5.0 package*. SPB Academic Publishing: 315 pp.
Rey, C. 1990. Flore et végétation du marais de Lozon (Verrayes-Vallée d'Aoste). *Rev. Valdôtaine d'Hist. Nat*., 44: 5-21.
Steiner, G.M. 1993. Scheuchzerio-Caricetea fuscae. Oxycocco-Sphagnetea. In: Grabherr G. & L. Mucina, *Die Pflanzengesellschaften Österreichs; Teil II, Natürliche waldfreie Vegetation*. Gustav Fischer Verlag Jena, Stuttgart, New York: 131-181.
Ter Braak, C.J.F. & P.F.M. Verdonschot. 1995. Canonical correspondence analysis and related multivariate methods in aquatic ecology. *Aquatic Sciences*, 57(3): 255-289.
Ter Braak, C.J.F. 1996. General introduction. In: C.J.F. Ter Braak, *Unimodal models to relate species to environment*. DLO Agricultural Mathematics Group, Wageningen, The Netherlands. 1-18.
Ter Braak, C.J.F. & P. Šmilauer. 1998. *CANOCO Reference Manual and User's Guide to Canoco for Windows*. Centre for Biometry Wageningen: 351 pp.
Zavagno, F., R. Falco, R. Ferranti, R. Zanchi. 2001. Biocenosi di torbiera e possibili modelli interpretativi. *Braun-Blanquetia*, 31: 33-38.