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THE VEGETATION OF WETLANDS IN THE SOUTHERN CARNIAN ALPS (ITALY)

LA VEGETAZIONE DEGLI AMBIENTI UMIDI DELLE ALPI CARNICHE MERIDIONALI

Abstract - Wetlands are fairly common in the Carnian Alps, especially in the inner sector of the range, mainly formed of silicate rocks dating back to the Paleozoic. A great moisture surplus allows water to seep out over gently inclined slopes which are extensively covered by sedge fens (*Drepanoclado revolventis-Trichophoretum cespitosi*). On steeper slopes water usually flows on the surface giving rise to spring fens rich in mosses (*Cratoneuretum falcati, Bryo-Philonotidetum seriatae*, community of *Cardamine amara*). More complex mire types develop on level relief, ranging from transitional mires covered by a mixture of rich fens (*Drepanoclado-Trichophoretum*), poor fens (*Caricetum nigrae*), *Sphagnum* carpets (*Eriophoro-Trichophoretum cespitosi*) and hummocks (*Sphagnetum magellanici*), and bog scrubs (*Pino mugo-Sphagnetum*), to ombrosoligenous mires. This latter mire type is represented by a typical example of well-preserved saddle mire including a dome-raised sector covered by a prostrate pine scrub (*Pino mugo-Sphagnetum*) and wet hollows (*Caricetum limosae*), and a flat sector covered by *Sphagnum* carpets and low hummocks (*Eriophoro-Trichophoretum cespitosi* and *Sphagnetum magellanici*). Both areas are surrounded by a narrow lagg colonized by a *Carex juncella* swamp. Mire water is subneutral to slightly acidic and fairly rich in nutrients in fens, springs and laggs as well. By contrast, mire water is acidic and nutrient-poor both in bogs and poor fens, with no sharp difference between them. Hence, there are often great difficulties in evaluating the trophic status of mire sites and/or sectors (viz. ombrotrophy vs. minerotrophy) based on hydrochemistry only.

Key words: Hydrochemistry, Mire typology, Phytosociology, Syntaxonomy, Wetlands.

Riassunto breve - *Nelle Alpi Carniche gli ambienti umidi sono piuttosto diffusi, soprattutto nel settore interno costituito in prevalenza da rocce silicee poco permeabili. Il clima umido, caratterizzato da un eccesso di precipitazioni rispetto all'evapotraspirazione potenziale, favorisce lo sviluppo di torbiere basse anche sui versanti in pendio, purchè non troppo ripidi. L'associazione vegetale dominante in questi habitat è il* Drepanoclado revolventis-Trichophoretum cespitosi. *Se l'inclinazione è maggiore il ruscellamento è più accentuato e la vegetazione corrispondente è quella tipica delle aree fontinali e dei ruscelli (*Cratoneuretum falcati, Bryo-Philonotidetum seriatae, *aggruppamento a* Cardamine amara*). Le aree pianeggianti ospitano corpi torbosi più cospicui, la cui vegetazione è per lo più costituita da un mosaico di prati torbosi a ciperacee (*Drepanoclado-Trichophoretum*), tappeti a sfagni (*Eriophoro-Trichophoretum cespitosi*), cumuli rilevati di sfagni (*Sphagnetum magellanici*) e*

arbusteti di torbiera (Pino mugo-Sphagnetum). *Tali complessi rientrano nel grande gruppo delle torbiere intermedie. In un solo caso, rappresentato da una torbiera posta a breve distanza dalla Casera Coltrondo (Alto Comelico), il corpo torboso presenta almeno in un settore un profilo convesso chiaramente rilevato rispetto all'area circostante. Si tratta di una torbiera ombrosoligena, la cui porzione sommitale è probabilmente alimentata soltanto da acqua piovana. La vegetazione di quest'area è costituita da arbusteti* (Pino mugo-Sphagnetum), *cumuli* (Sphagnetum magellanici) *e tappeti a sfagni* (Eriophoro-Trichophoretum), *intercalati a depressioni umide* (Caricetum limosae). *Ai margini l'accumulo di torba è molto ridotto e la vegetazione (aggruppamento a* Carex juncella) *risente in maniera assai netta del contatto con il substrato minerale. In questo habitat, come pure nelle torbiere piane e nei ruscellamenti, l'acqua ha reazione debolmente acida o subneutra. Nelle torbiere a sfagni, viceversa, l'acqua è fortemente acida e povera in nutrienti. Il chimismo delle acque non presenta però apprezzabili differenze tra le torbiere intermedie e quella ombrosoligena.*

Parole chiave: *Chimismo delle acque, Fitosociologia, Ruscellamenti, Sintassonomia, Torbiere.*

1. Introduction

Even though the Carnian Alps mostly have a rough relief, badly suitable for mire development, relatively vast areas show a more gentle morphology, especially in the interior of the chain. Here, wetlands are a fairly common feature of the landscape and an appreciable portion of the land surface is covered by peat.

The plant cover of these wetlands has much in common with that of peatlands in central and northern Europe. Of particular phytogeographic interest is the presence of some tracheophytes, mainly belonging to the circumboreal floristic element, which are rare all over the southern Alps (PIGNATTI, 1982), for lying close to the southern borderline of their distributional area in Europe. Most of them, viz. *Andromeda polifolia, Carex pauciflora, Drosera anglica* and *Vaccinium oxycoccos* s.l., are reported in early works of BOLZON (1920), PAMPANINI (1927) and ZENARI (1942). More recently, also *Scheuchzeria palustris* was included in this catalogue (GERDOL, 1980). Unfortunately, this latter species disappeared only few years later owing to the reclamation of the only small mire sector in which it throve.

Far less is known about the bryophyte component, the only checklist of mosses in the Carnian Alps dating back to the very beginning of this century (KERN, 1908). Some information in this respect can be drawn only from the papers of GERDOL (1981, 1986). Although the data available are still poor, it seems that the moss flora of the wetlands in the Carnian Alps look like that of vascular plants, at least in its general traits. There are a number of species in common with boreal peatlands, several of which do not occur south of the Alps in Italy. These include, besides some mosses and hepatics such as *Calliergon sarmentosum* (VENTURI & BOTTINI, 1884) and *Cladopodiella fluitans* (GERDOL, 1988), several species of peat mosses (genus *Sphagnum*) such as *S. angustifolium, S. fuscum, S. molle, S. rubellum* and *S. warnstorfii* (BOTTINI, 1919; GERDOL, unpublished).

Part of the recent work dealing with wetlands in the Carnian Alps focusses on some vegetational aspects of these habitats and pays a special attention to the syntaxonomy of plant communities. There are, hitherto, published accounts of the vegetation of: 1) oligotrophic hollows (GERDOL, 1980), 2) springs and stream-sides (GERDOL, 1986), 3) fens and 4) *Sphagnum* carpets (GERDOL, 1981). All of them show remarkable similarities with boreal peatlands as far as also vegetation is concerned.

The present paper is directly related to the preliminary contributions cited above and points to synthesizing the results of a twelve-year research on wetlands in the Carnian Alps. It has the main objective of typifying vegetation and aims, furthermore, at exploring the causal relationships between vegetational patterns and environment.

2. Material and methods

2.1. Description of the study area

The study area corresponds to the southern sector of the Carnian Alps. The Carnian Alps sensu stricto, i.e. excluding the Carnian Praealps as well as the southeasternmost sector of the Dolomites, have an E-W principal axis and are limited to the East by the river Slizza (Gailitz), to the North by the rivers Gail and Drava (Drau), to the West by the rivers Rio di Sesto (Sextenbach), Rio Padola and Piave, and to the South by the rivers Tagliamento and Fella (fig. 1). The limit between the northern and the southern sectors of the Carnian Alps runs along the main axial ridge of the inner range, which largely coincides with the Italian-Austrian borderline and reaches its highest elevation on M. Coglians (2780 m). The areas included within the Italian territory administratively belong to the provinces of Udine, Belluno and Bolzano (Bozen).

The Carnian Alps are made of a large variety of bedrocks dating back to different geologic times, ranging from early Paleozoic to late Mesozoic (SELLI, 1963; VENTURINI, 1990). The Paleozoic formations mainly consist of silicate rocks, whose outcrops are located in the interior of the chain. By contrast, the outer sector is essentially formed of Mesozoic carbonate rocks. As can be easily foreseen, wetlands are almost exclusive of the former.

Climate can be considered cool temperate (MENNELLA, 1972; FLIRI, 1975), with mean annual temperatures averaging 7-8 °C at 800-900 m above sea level. Precipitation is clearly enriched to the East where two distinct maxima can be observed, respectively in November and June. By contrast, climate is drier and more continental to the West where an only maximum occurs in late spring-early summer (fig. 1). Further aspects of the climate will be considered in more detail below.

The landscape in the innermost sector of the Carnian Alps, where the big majority of the wetlands are concentrated, is essentially characterized by conifer forests up

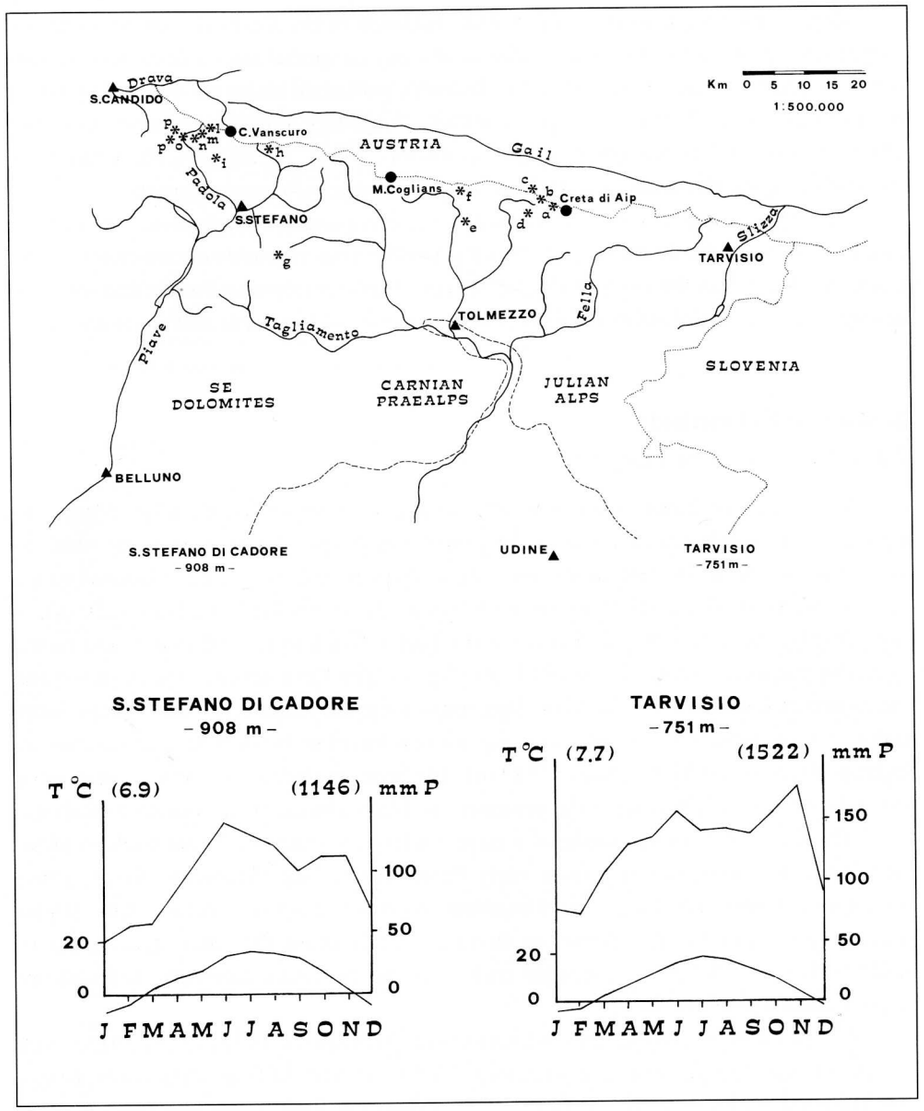

Fig. 1 - Geographic map of the study area with the climatic diagrams of two meteorologic stations located at a comparable elevation in the eastern (Tarvisio) and in the western (S. Stefano di Cadore) sector of the Carnian Alps. The 300 m contour line is reported.

- *Cartina schematica dell'area geografica indagata con i diagrammi pluviometrici di due stazioni poste alle estremità della catena ad altezza simile. Il tratteggio indica l'isoipsa dei 300 m.*

to ca. 2000 m (DEL FAVERO et al., 1990). Mixed forests (*Luzulo-Abietetum* Oberd. 1957) of Norway spruce (*Picea excelsa*) and silver fir (*Abies alba*) dominate in the lower belt (ca. 1000-1500 m), above which Norway spruce usually forms almost pure stands (*Homogyno-Piceetum* Zukrigl 1973). Larch (*Larix decidua*) and Arolla pine (*Pinus cembra*), the latter especially to the West, are the dominant tree species in the uppermost narrow forest belt (*Vaccinio-Rhododendretum ferruginei laricetosum* Br.-Bl. 1927: ca. 1850-2000 m). Above treeline an ericaceous heath (*Vaccinio-Rhododendretum ferruginei typicum* Br.-Bl. 1927) covers most of the slopes up to the highest elevations at which wetlands still occur.

2.2. Exploratory survey

A number of wetlands were preliminary explored during a series of field surveys carried out in the years 1979-1981. Only the wetlands located above 1000 m were retained. This led, however, to exclude only small fragments of mires in the main thalwegs. Also lakes were disregarded, since an account of the plant cover of montane lakes in the Carnian Alps was already provided by SBURLINO (1978).

Only a part of the sites were selected for the purposes of this study. The main selection criterion was based upon conservation status. Only the wetlands (and/or wetland sectors) bearing no evident sign of heavy alteration, such as drainage, amelioration and peat extraction, as well as intensive grazing, were considered. However, some of the sites investigated are occasionally grazed, always with low loadings. None of them is subjected to regular mowing.

2.3. Field work

The vegetation was sampled at the selected sites in the years 1985-1986 by the BRAUN-BLANQUET (1964) approach. The number of sample plots (relevés) established at each site was almost proportional to the site area as well as to the range of vegetational diversity as could be assayed by visual inspection. The location of most plots was marked by means of a woody stake.

All sites but two were the object of a further inspection during the summer of 1992. The latter was performed immediately after a rainy period when all wetlands were well hydrated. The pH and electrical conductivity, the latter corrected for H^+ (SJÖRS, 1950), were measured in the field by portable instruments at a number of plots whose vegetation had been investigated previously. In addition, some water samples were collected along transects at four sites for chemical analyses. All samples were collected from open pools, always avoiding peat compaction. The water was filtered, placed in 100-mL acid-washed bottles and deep frozen until analysis.

Site	Pr.	Elev. (m)	Substrate
a) Valle di Aip	UD	1680-1780	Quartz sandstones (Auernig Group), Upper Carboniferous
b) Piani di Lanza	UD	1750-1780	Quartz conglomerate and sandstones (Rattendorf Group), Early Permian
c) Hüttenkofel	Au	1850	Rattendorf Group, see above
d) M. Zermula	UD	1690	Reef limestones, Devonian
e) Valpudia	UD	1180	Sandstones-siltstones-shales (Hochwipfel Form.), Carboniferous
f) Casera Pramosio	UD	1700	Hochwipfel Formation, see above
g) Forc. Lavardet	UD	1530	Wine-red sandstones (Val Gardena Form.), Upper Permian
h) Val Dignas	BL	1800	Multicoloured shales and siltstones (Val Visdende Form.), Ordovician
i) Col Rosson	BL	2050-2150	Sericitic-chloritic quartz phyllites Paleozoic s.l., partly pre-Ordovician
l) Col Quaternà	BL	2300	Quartz phyllites, see above
m) North of C.ra Coltrondo	BL	1900	Quartz phyllites, see above
n) West of C.ra Coltrondo	BL	1830	Quartz phyllites, see above
o) Nemes Alm	BZ	1800-1850	Quartz phyllites, see above
p) Col della Croce	BZ	1720	Quartz phyllites, see above
q) Oberkreuzmoos	BZ	1730	Quartz phyllites, see above

Tab. 1 - List of the wetlands investigated (from the East to the West).
UD=province of Udine; BL=province of Belluno; BZ=province of Bolzano (Bozen); Au=Austrian territory.
- *Elenco degli ambienti umidi indagati (da Est a Ovest).*

2.4. Laboratory work

All floristic relevés were grouped into a table which was then subjected to a numerical classification by cluster analysis. The clusters resulting from this classification were considered as vegetation types and then evaluated from the syntaxonomical viewpoint. The floristic nomenclature follows: PIGNATTI (1982) for vascular plants, with the exceptions of *Carex magellanica* Lam., *Carex nigra* (L.) Richard, *Dactylorhiza fuchsii* (Druce) Soò and *Melampyrum pratense* L. ssp. *paludosum* (Gaud.-B.) Ronn.; CORLEY et al. (1981) for mosses; ANDRUS (1980) for *Sphagnum*; and GROLLE (1983) for hepatics.

The water samples were analysed for major cations, viz. Na^+, K^+, Ca^{2+} and Mg^{2+}, by atomic absorption photometry. Lanthanum was added when analysing calcium and magnesium in order to reduce anionic interference.

A description of the classification techniques and indices can be found in ORLOCI (1978). The cover estimates of floristic data were converted from the Braun-Blanquet ordinal scale into numerical values as described by VAN DER MAAREL (1979). Further statistical computations were performed using the SPSSPC+ package for IBM personal computers (NORUSIS, 1986).

3. Results and discussion

3.1. Geographical distribution of wetlands

All of the sites chosen lie in the inner sector of the range which was defined as the "Endocarnian system" (POLDINI, 1974). The big majority of them develop on silicate rocks, with the only exceptions of a peatland on M. Zermula, settled on limestone, and partly of the peatland complex of Valle di Aip, influenced by seepage water running through carbonate debris (tab. 1).

There is a clear concentration of wetlands in the western part of the study area (fig. 1). This seems to be determined more by lithological grounds, silicate outcrops being much more frequent in that region (SELLI, 1963), than by the climatic differences outlined above. As shown by the very high values of the Tamm's index of moisture (H), calculated according to formula(1)

$$H = P - 29*(7.63+T)^{(1)}$$

where P is the mean annual precipitation (mm) and T the mean annual temperature (°C), there is a large moisture surplus over the whole area investigated (tab. 2).

Station	H
Tarvisio (751 m)	1077
Pontebba (561 m)	1307
Collina (1189 m)	1156
Forni di sopra (907 m)	1013
S. Stefano di Cadore (908 m)	725
Passo della Mauria (1298 m)	1111
South of Passo M. Croce Comelico (Kreuzbergpass, 1400 m)	871
Sesto (Sexten, 1300 m)	518

Tab. 2 - Tamm's index of humidity (H) for some meteorological stations in the Carnian Alps (from the East to the West).
- *Indice di umidità di Tamm (H) ricavato dai dati meteorologici di alcune stazioni nelle Alpi Carniche (da Est a Ovest).*

This clearly enhances the development of wetlands. The formation of sloping fens is greatly promoted under such a moist climate, while raised bogs are unlikely to develop owing to the onset of erosion phenomena (TAYLOR, 1983). Also the relief morphology, characterized by the lack of flat terrains, hinders the accumulation of ombrogenous peat, as commonly happens in the Alps (KAULE, 1974a; GERDOL, unpublished).

Only at the northwesternmost corner of the study area does the Tamm's index fall closer to the threshold value of ca. 500 under which raised bogs can develop without undergoing heavy erosion (ØKLAND, 1989).

A further insight into wetland typology will be attempted below.

3.2. Vegetation typology

The fifteen main clusters resulting from the numerical classification of the floristic data (fig. 2) are considered as the main vegetation types in the wetlands of the Carnian Alps.

These clusters merge into two big groups, of which one comprises the vegetation of raised habitats dominated by hummock-forming *Sphagna* (clusters SM to PS, fig. 2), and the other the vegetation of level habitats ranging from wet meadows to bog hollows, and spring fens as well (clusters ES to ET, fig. 2).

Even though most of those vegetation types can be interpreted as associations in the Braun-Blanquet system, their arrangement in the dendrogram is far from reflecting the syntaxonomical hierarchy.

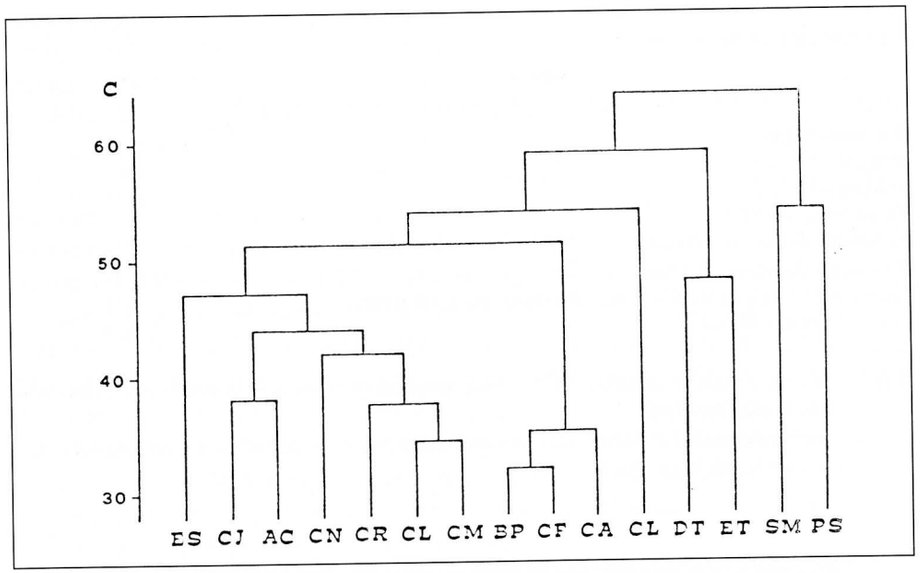

Fig. 2 - Synthetic classification dendrogram of the floristic relevés by sum of squares agglomeration based on the chord distance. Abbreviations for the vegetational types as in tab. 3.
- *Dendrogramma sintetico di classificazione dei rilievi ottenuto con il metodo della somma dei quadrati basata sulla distanza della corda. Le abbreviazioni per i tipi vegetazionali corrispondono a quelle in tab. 3.*

For instance, the vegetation of *Sphagnum* carpets (cluster ET, fig. 2) appears more similar to that of sloping fens (cluster DT), than to *Sphagnum* hummocks (cluster SM), although belonging to the same phytosociological class (*Oxycocco-Sphagnetea*) as the latter. Such a discrepancy between overall floristic similarity and syntaxonomy frequently occurs when large sets of data are treated by cluster analysis (GERDOL & TOMASELLI, 1993).

For the sake of an easier reading, vegetation will be described according to physiognomic groups largely corresponding to high-rank units in the Braun-Blanquet system. The relationships between syntaxonomy and floristic similarity as resulting from cluster analysis can be rapidly inspected by comparing fig. 2 and tab. 3.

3.2.1. Spring fens

Water frequently seeps up through the ground over gently inclined slopes in the study region as a consequence of the high moisture surplus (see above). Where the relief slope is low (up to 5‰), such a seepage gives rise to sloping fens. By greater slope angles water usually flows downslope in narrow streamlets which are colonized, especially along their sides, by a peculiar vegetation in which three different plant communities can be distinguished.

Cratoneuretum falcati (CF, tab. 4). Corresponds to the vegetation of streamlets flowing on carbonate-rich substrates and/or debris. Hence vegetation has a moss layer rich in tuff-forming plants, especially *Cratoneuron commutatum* var. *falcatum* which characterizes this association. As all comparable associations, the *Cratoneuretum falcati* is included in the class *Montio-Cardaminetea* which is made up of the only order *Montio-Cardaminetalia*. The *Cratoneuretum falcati* clearly belongs to the alliance of calcareous spring-moss carpets (*Cratoneurion commutati*), as shown by the common presence of *Philonotis calcarea* and *Silene alpestris*, both exclusive of carbonate-rich spring habitats.

The dominant tracheophyte, however, is *Caltha palustris* ssp. *laeta* which is considered as a companion. Other companions (*Carex nigra, Tofieldia calyculata* and *Willemetia stipitata*; tab. 4) point to a certain floristic similarity with the adjoining rich fens of the *Drepanoclado-Trichophoretum* (see below).

Water in the habitats of the *Cratoneuretum falcati* is obviously alkaline and moderately rich in electrolytes (tab. 18).

Community of *Cardamine amara* (CA, tab. 5). Is developed on carbonate-rich substrates and is also included in the alliance *Cratoneurion commutati*. Tuff-forming mosses are less abundant than in the *Cratoneuretum falcati*. Due to the low diagnostic power of the leading species *Cardamine amara* (see OBERDORFER, 1992), this community cannot be defined at the association level.

Montio-Cardaminetea Br.-Bl. et Tx. ex Klika et Had. 1944
Montio-Cardaminetalia Pawl. 1928
Cratoneurion commutati W. Koch 1928
CF - *Cratoneuretum falcati* Gams 1927
CA - Community of *Cardamine amara*
Cardamino-Montion Br.-Bl. 1925
BP - *Bryo-Philonotidetum seriatae* Luq. 1926
subass. *typicum*
subass. *bryetosum schleicheri*

Scheuchzerio-Caricetea nigrae (Nordh. 1936) Tx. 1937
Scheuchzerietalia palustris Nordh. 1936
Caricion lasiocarpae Vanden Bergh. apud Lebrun et al. 1949
CR - *Caricetum rostratae* Rübel 1912 ex Osv. 1923
CJ - Community of *Carex juncella*
Rhynchosporion albae W. Koch 1926
CL - *Caricetum limosae* Paul 1910 ex Osv. 1923 em. Dierssen 1982
subass. *typicum*
subass. *scorpidietosum scorpioidis*
Caricetalia nigrae (W. Koch 1926) Nordh. 1936
Caricion nigrae W. Koch 1926 em. Klika 1934
ES - *Eriophoretum scheuchzeri* Fries 1913 subass. *drepanocladetosum exannulati*
CN - *Caricetum nigrae* Br.-Bl. 1915
CM - *Caricetum magellanicae* Osv. 1923
Caricetalia davallianae Br.-Bl. 1949
Caricion davallianae Klika 1934
DT - *Drepanoclado revolventis-Trichophoretum cespitosi* Nordh. 1928 em. Dierssen 1982

Molinio-Arrhenatheretea Tx. 1937
Molinetalia caeruleae W. Koch 1926
Calthion palustris Tx. 1937
AC - *Angelico-Cirsietum palustris* Balatova-Tulackova 1973

Oxycocco-Sphagnetea Br.-Bl. et Tx. 1943
Sphagnetalia magellanici (Pawl. 1928) Kästn. et Flössn. 1933
Sphagnion magellanici Kästn. et Flössn. 1933
SM - *Sphagnetum magellanici* (Malcuit 1929) Kästn. et Flössn. 1933
subass. *typicum*
subass. *sphagnetosum fusci*
subass. *sphagnetosum nemorei*
ET - *Eriophoro-Trichophoretum cespitosi* (Zlatnik 1928, Rudolph et al. 1928) em. Rübel 1933
PS - *Pino mugo-Sphagnetum* Kästn. et Flössn. 1933 em. Neuhäusl 1969 corr. Dierssen 1977

Tab. 3 - Syntaxonomical arrangement of the vegetation.
- *Inquadramento sintassonomico della vegetazione.*

Rel. n.	1	2	3
Site	d	a	a
Rel.area (sqm)	20	10	10
Cover (%) herb layer	70	60	70
Cover (%) moss layer	80	70	90
Rare species	3	5	5
N. of species	15	13	17
ASSOCIATION			
Cratoneuron commutatum var. falcatum	2	3	2
ALLIANCE			
Philonotis calcarea	1	+	+
Silene alpestris		2	1
ORDER, CLASS			
Epilobium alsinifolium	1	+	+
Brachythecium rivulare	2		
Cratoneuron decipiens	1		
COMPANIONS			
Caltha palustris ssp. laeta	4	2	2
Euphrasia rostkoviana	1	+	+
Bryum pseudotriquetrum		1	3
Cardamine rivularis	2		1
Carex nigra	1		2
Deschampsia caespitosa	1	+	
Alchemilla vulgaris	+	+	
Potentilla erecta	+		+
Willemetia stipitata	+		+
Tofieldia calyculata		+	+

Tab. 4 - *Cratoneuretum falcati.* (Abbrev. for sites as in tab. 1).
- Cratoneuretum falcati. *(Sigle per le stazioni come in tab. 1).*

Site	g
Rel.area (sqm)	10
Cover (%) herb layer	50
Cover (%) moss layer	40
N. of species	17
LEADING SPECIES	
Cardamine amara	1
ALLIANCE,ORDER, CLASS	
Scapania paludicola	1
Cratoneuron commutatum var. falcatum	1
COMPANIONS	
Campylium stellatum	1
Willemetia stipitata	1
Bryum pseudotriquetrum	1
Juncus triglumis	1
Drepanocladus revolvens	1
Carex ferruginea	1
Carex oederi	1
Potentilla erecta	+
Pinguicula vulgaris	+
Caltha palustris ssp. laeta	+
Vaccinium vitis-idaea	+
Homogyne alpina	+
Poa alpina	+
Dactylorhiza fuchsii	r

Tab. 5 - Community of *Cardamine amara.* (Abbrev. for sites as in tab. 1).
- *Aggruppamento a* Cardamine amara. *(Sigle per le stazioni come in tab. 1).*

Water in habitats of this community is alkaline and richer in electrolytes than in the previous association (tab. 18).

Bryo-Philonotidetum seriatae (BP, tab. 6). Corresponds to the vegetation of springs and stream-sides on silicate grounds. The character species of this association, viz. *Philonotis seriata*, occurs only in two of the three relevés available (tab. 6). The third relevé, by contrast, has *Bryum schleicheri* as dominant moss species, and is included in a distinct subassociation (*Bryo-Philonotidetum seriatae bryetosum schleicheri*), probably linked to sites occasionally trampled by cattle. *Stellaria alsine* and *Dicranella palustris*, being character species of the *Cardamino-Montion*, point to including the *Bryo-Philonotidetum seriatae* in that alliance which include the vegetation of springs and stream sides on silicate substrates.

There are, however, several species transgressive from the *Cratoneurion commutati* (*Silene alpestris, Epilobium alsinifolium* and *Cratoneuron commutatum* var. *falcatum*).

Rel. n.	1	2	3
Site	b	f	a
Rel.area (sqm)	5	10	20
Cover (%) herb layer	60	60	80
Cover (%) moss layer	60	40	50
Rare species	6	6	6
N. of species	20	22	17
ASSOCIATION			
Philonotis seriata	+	1	
SUBASS. BRYETOSUM SCHLEICHERI			
Bryum schleicheri			2
ALLIANCE			
Dicranella palustris	2	+	
Stellaria alsine		+	
ORDER, CLASS			
Cratoneuron decipiens	2		2
Saxifraga stellaris	+	+	
Silene alpestris	+	+	
Cratoneuron commutatum var. falcatum	+	+	
Brachythecium rivulare	+		+
Epilobium alsinifolium	+		+
Cardamine amara	+		
COMPANIONS			
Caltha palustris ssp. laeta	2	1	4
Allium schoenoprasum ssp. sibiricum	+	+	+
Cardamine rivularis		1	2
Deschampsia caespitosa		2	+
Carex nigra	1		1
Bryum pseudotriquetrum	1	+	
Alchemilla gr. vulgaris	+	1	
Carex frigida	+	1	
Poa alpina		+	+
Willemetia stipitata		+	+

Tab. 6 - *Bryo-Philonotidetum seriatae.* (Abbrev. for sites as in tab. 1).
- Bryo-Philonotidetum seriatae. *(Sigle per le stazioni come in tab. 1).*

Rel. 1-2: subass. *typicum*;
Rel. 3: subass. *bryetosum schleicheri.*

Rel. n.	1	2	3
Site	a	a	a
Rel.area (sqm)	4	20	20
Cover (%) herb layer	60	90	80
Cover (%) moss layer	5	40	60
Rare species	-	-	9
N. of species	4	7	15
ASSOCIATION			
Carex rostrata	3	5	3
ALLIANCE, ORDER			
Calliergon giganteum		2	2
Equisetum fluviatile (d)		1	1
CLASS			
Eriophorum angustifolium	1	+	1
Carex nigra	+	1	1
Drepanocladus exannulatus	1		
Willemetia stipitata			1
Carex stellulata		+	
Carex lepidocarpa		+	

Tab. 7 - *Caricetum rostratae.* (Abbrev. for sites as in tab. 1).
- Caricetum rostratae. *(Sigle per le stazioni come in tab. 1).*

Such a co-occurrence of character plants of both hard-water and soft-water spring vegetation is a common feature in most spring communities (GEISSLER, 1976), and is probably determined by the buffering power of bicarbonate ions enriched in flowing water (GERDOL & TOMASELLI, 1988).

As could be expected from the indicator values of plants, water in the habitats of the *Bryo-Philonotideum seriatae* has a subneutral reaction although being poorer in electrolytes than in the *Cratoneurion* communities (tab. 18).

3.2.2. Hollows and pools

Caricetum rostratae (CR, tab. 7). Is a tall-sedge association characterized by *Carex rostrata*, usually achieving dominance. The *Caricetum rostratae* has a wide ecological amplitude extending from ombrotrophic pools to nutrient-rich habitats, often transgressive to the *Magnocaricion* (DIERSSEN, 1982). In the study area the *Caricetum rostratae* is restricted to small mesotrophic pools in calcium-rich fens. As commonly happens in the *Caricetum rostratae*, the relevés are species-poor but the syntaxonomical arrangement of this association (class *Scheuchzerio-Caricetea nigrae*, order *Scheuchzerietalia palustris* and alliance *Caricion lasiocarpae*, see tab. 3) is uncontroversial owing to the presence of several character species of those syntaxa in the relevés (tab. 7).

Water in the habitats of the *Caricetum rostratae* is slightly acidic and moderately rich in electrolytes (tab. 18).

Rel. n.	1	2
Site	n	n
Rel.area (sqm)	20	10
Cover (%) herb layer	90	80
Cover (%) moss layer	70	30
N. of species	20	20
LEADING SPECIES		
Carex juncella	3	3
ALLIANCE,ORDER		
Sphagnum contortum	2	1
Carex rostrata	+	1
Menyanthes trifoliata		1
Potentilla palustris		1
Sphagnum flexuosum	+	
Calliergon giganteum		+
CLASS		
Carex canescens	1	+
Viola palustris	+	1
Juncus filiformis	+	+
Sphagnum warnstorfii	2	
Carex stellulata	+	
Willemetia stipitata	+	
Calliergon stramineum	+	
Swertia perennis	+	
Carex lepidocarpa	+	
Campylium stellatum		+
Eriophorum angustifolium		+
Agrostis canina		+
COMPANIONS		
Hypnum lindbergii	+	2
Carex panicea	+	+
Potentilla erecta	+	+
Luzula sudetica	+	+
Nardus stricta		2
Calliergonella cuspidata	1	
Valeriana dioica	1	
Caltha palustris ssp. laeta	1	
Deschampsia caespitosa	+	
Galium palustre		+
Trollius europaeus		+

Tab. 8 - Community of *Carex juncella*. (Abbrev. for sites as in tab. 1).
- *Aggruppamento a* Carex juncella. *(Sigle per le stazioni come in tab. 1).*

Community of *Carex juncella* (CJ, tab. 8). Corresponds to the swamp vegetation, dominated by *Carex juncella*, settled in the peripheric sector of an ombrosoligenous mire (see below). *Carex juncella*, belonging to the group of *Carex nigra*, is essentially distinguished based on its habitus forming compact tussocks, and also by its prominently veined utricles, but its taxonomic status has not yet been clearly defined (CHATER, 1980).

A *Caricetum juncellae* was described in the floodplains of Yakutia (central-northern Asia), as a glycophyte association included in the class *Calamagrostietea langsdoffii* (MIRKIN et al., 1985) which has practically no species in common with mire vegetation. On the other hand, *Carex juncella* swamps probably are more common at the margin of mires in Europe than so far reported in the phytosociological literature (PERSSON, 1961). Due to the few data available, this vegetation cannot be typified at the association level

Rel. n.	1	2	3	4	5	%
Site	n	n	n	a	o	
Rel.area (sqm)	4	4	2	2	2	P
Cover (%) herb layer	50	40	70	60	90	r
Cover (%) moss layer	100	90	70	40	65	e
N. of species	8	7	7	7	6	s
ASSOCIATION						
Carex limosa	1	2	2	2	2	100
SUBASS. SCORPIDIETOSUM SCORPIOIDIS						
Scorpidium scorpioides					5	20
ALLIANCE, ORDER						
Carex rostrata	2	1	+	1	1	100
Gymnocolea inflata	3	3	3	1		80
Sphagnum flexuosum	2	2	1			60
Drepanocladus fluitans	+	+	1			60
Drosera anglica			1		+	40
Menyanthes trifoliata	1					20
Calliergon trifarium					1	20
Lepidotis inundata					+	20
CLASS						
Sphagnum subsecundum				2		20
Carex nigra				1		20
Drepanocladus exannulatus				1		20
Eriophorum angustifolium				1		20
COMPANIONS						
Sphagnum compactum	1	1				40
Carex pauciflora	+		+			40
Drosera rotundifolia		1				20

Tab. 9 - *Caricetum limosae.* (Abbrev. for sites as in tab. 1).
- Caricetum limosae. *(Sigle per le stazioni come in tab. 1).*
Rel. 1-4: subass. *typicum*;
Rel. 5: subass. *scorpidietosum scorpioidis.*

and is, therefore, designated as "community of *Carex juncella*". No doubt this community belongs to the class *Scheuchzerio-Caricetea nigrae*. Its inclusion in the alliance *Caricion lasiocarpae*, order *Scheuchzerietalia palustris* (see tab. 3) seems consistent, for several character species of those syntaxa occurring in the relevés (tab. 8), even though there are a number of species transgressive from the *Caricetalia nigrae* such as *Carex canescens, Viola palustris, Juncus filiformis, Carex stellulata, Calliergon stramineum* and *Agrostis canina*, which point to close affinities with the *Caricetalia* fens.

Mire water in the habitat of this community is slightly acidic and moderately rich in electrolytes (tab. 18).

Caricetum limosae (CL, tab. 9). Corresponds to the vegetation of mire pools and hollows, characterized by *Carex limosa* and included in the alliance *Rhynchosporion albae*, order *Scheuchzerietalia palustris* (tab. 3). The *Caricetum limosae* is clearly differentiated into two subgroups, sharply separated also in the classification dendrogram (fig. 2),

which can be interpreted as subassociations following the recent syntaxonomic literature on this subject (DIERSSEN & REICHELT, 1988).

The first subgroup (tab. 9, rel. 1-4) corresponds to the subassociation typicum, lacking true differential species but showing a remarkable abundance of hepatics, especially *Gymnocolea inflata*, as well as of peat mosses of the sect. *Cuspidata* (*Sphagnum flexuosum*). The second subgroup (tab. 9, rel. 5) corresponds to the subassociation *scorpidietosum scorpioidis*, differentiated by the moss *Scorpidium scorpioides*.

Such floristic differences between the two subassociations are well interpretable in terms of environment, the *Caricetum limosae* typicum being linked to bogs or bog-like habitats with acidic water poor in electrolytes, whereas the *Caricetum limosae scorpidietosum scorpioidis* is found in fen pools with moderately acidic water richer in electrolytes (tab. 18).

3.2.3. Fens

Eriophoretum scheuchzeri (ES, tab. 10). Corresponds to the fen vegetation in the upper subalpine-lower alpine vegetation belt, well above treeline.

The *Eriophoretum scheuchzeri* is characterized by *Eriophorum scheuchzeri* and included in the alliance *Caricion nigrae*, order *Caricetalia nigrae*, class *Scheuchzerio-*

Rel. n.	1	2	3
Site	1	1	1
Rel.area (sqm)	10	10	10
Cover (%) herb layer	60	60	65
Cover (%) moss layer	60	90	70
N. of species	8	10	12
ASSOCIATION			
Eriophorum scheuchzeri	2	2	1
ALLIANCE, ORDER			
Drepanocladus exannulatus	5	5	3
Juncus filiformis	+	1	1
Carex stellulata		+	
Carex canescens			+
CLASS			
Carex nigra	+	1	2
Eriophorum angustifolium			+
COMPANIONS			
Cerastium cerastioides	2	+	+
Saxifraga stellaris	+	+	+
Philonotis seriata	+	1	
Philonotis tomentella	+		+
Deschampsia caespitosa		+	+
Epilobium anagallidifolium			+
Dicranella palustris			+
Poa alpina			+

Tab. 10 - *Eriophoretum scheuchzeri drepanocladetosum exannulati*. (Abbrev. for sites as in tab. 1).

Caricetea nigrae (tab. 3). Owing to the dominance of *Drepanocladus exannulatus* in the moss layer, all relevés can be included in the subassociation *drepanocladetosum exannulati* (DIERSSEN, 1982). There are, in addition, some transgressive species from the class *Montio-Cardaminetea* such as *Saxifraga stellaris, Philonotis seriata, Philonotis tomentella* and *Dicranella palustris*, listed among the companions in the phytosociological table (tab. 10). Such species indicate a certain degree of surface water flow. Furthermore, two species transgressive from the class *Salicetea herbaceae* (*Cerastium cerastioides* and *Epilobium anagallidifolium*) point to a prolonged snow cover.

The *Eriophoretum scheuchzeri* is settled on fairly inclined slopes (5-10‰) made of silicate rocks. Mire water is acidic and rather poor in electrolytes (tab. 18).

Caricetum nigrae (CN, tab. 11). Corresponds to the poor-fen vegetation developed on flat terrains having a silicate substrate. This association is syntaxonomically well characterized owing to the presence of all three character species, viz. *Juncus filiformis, Agrostis canina* and *Carex canescens*, although the two latter are rather rare. There are, in addition, many species characterizing the higher-rank syntaxa, viz. *Caricion nigrae, Caricetalia nigrae* and *Scheuchzerio-Caricetea nigrae* (see tab. 11).

Two subgroups can be distinguished within the *Caricetum nigrae*: the one (tab. 11, rel. 1-4) richer in *Trichophorum caespitosum*, linked to better drained sites; and the other (tab. 11, rel. 5-8) richer in *Sphagnum subsecundum*, linked to wetter habitats. They are considered as variants.

Mire water in the habitats of the *Caricetum nigrae* is moderately acidic and rather poor in electrolytes (tab. 18).

Caricetum magellanicae (CM, tab. 12). Corresponds to the vegetation of flat pools developed in poor fens at the high-elevation sites and has *Carex magellanica* as character species. *Carex magellanica* gradually replaces its allied species *Carex limosa* as far as elevation increases, but is usually confined to somewhat drier habitats. Accordingly, the *Caricetum magellanicae* is included in the *Caricetalia nigrae* rather than in the *Scheuchzerietalia palustris*. Several character species of alliance, order and class (see tab. 3) occur in the only relevé available (tab. 12).

No data are available, unfortunately, on mire-water chemistry in the habitat of the *Caricetum magellanicae*.

Drepanoclado revolventis-Trichophoretum cespitosi (DT, tab. 13). Corresponds to the far most widespread rich-fen vegetation in the study area, having *Trichophorum caespitosum* as dominant species in the field layer and *Campylium stellatum* as most frequent species in the bottom layer. The characterization of the *Drepanoclado-Trichophoretum* at

Rel. n.	1	2	3	4	5	6	7	8	%
Site	b	b	c	m	q	f	f	p	
Rel.area (sqm)	30	30	20	50	30	10	10	20	p
Cover (%) herb layer	90	95	90	95	95	90	85	90	r
Cover (%) moss layer	50	60	30	60	50	80	50	70	e
Rare species	1	-	7	9	7	6	3	7	s
N. of species	16	16	23	24	23	22	22	32	
ASSOCIATION									
Juncus filiformis	1	+	+	+		2	1	+	87
Agrostis canina			+		+				25
Carex canescens			+						12
VARIANT OF SPHAGNUM SUBSECUNDUM									
Sphagnum subsecundum					1	4	+	1	62
ALLIANCE, ORDER									
Viola palustris	1	1	2	+	2	2	1	+	100
Carex stellulata	2	1	1		1	1	+	1	87
Drepanocladus exannulatus	2	2	1	1			2		62
Calliergon stramineum		1	+		+		+	1	62
CLASS									
Carex nigra	2	2	4	3	2	3	4	3	100
Eriophorum angustifolium	+	1	+	+	2	+	+	+	100
Carex rostrata	2	+	1	+	3				62
Bartsia alpina	+	1		+	+			1	62
Willemetia stipitata		+				1	+	1	50
Carex lepidocarpa			+	+				+	37
Parnassia palustris			+		+			+	37
Sphagnum warnstorfii					2			1	25
Sphagnum lescurii	1	1							25
Carex davalliana				+				1	25
Campylium stellatum					+			1	25
Juncus alpino-articulatus							+	1	25
Carex limosa	+			+					25
Riccardia pinguis			+					+	25
COMPANIONS									
Potentilla erecta	+	+	+	+	1	1	+	1	100
Trichophorum caespitosum	1	3	+	2				1	62
Molinia coerulea	+	1		+	1	1			62
Scapania irrigua	1		+	+			+	+	62
Nardus stricta	+	+				+	+	+	62
Luzula sudetica				+	+	+	+	+	62
Deschampsia caespitosa		+				+	+	+	50
Festuca rubra					+	+	+	+	50
Alchemilla gr. vulgaris						+	+	+	37
Allium schoenoprasum ssp. sibiricum						+	+	+	37

Tab. 11 - *Caricetum nigrae.* (Abbrev. for sites as in tab. 1).
- Caricetum nigrae. *(Sigle per le stazioni come in tab. 1).*

Rel. 1-4: typical variant;
Rel. 5-8: variant of *Sphagnum subsecundum.*

Site	1
Rel.area (sqm)	10
Cover (%) herb layer	70
Cover (%) moss layer	90
N. of species	8
ASSOCIATION	
Carex magellanica	3
ALLIANCE, ORDER	
Calliergon sarmentosum	4
Drepanocladus exannulatus	1
Carex canescens	+
CLASS	
Carex nigra	1
Carex stellulata	1
Eriophorum angustifolium	1
Carex oederi	+

Tab. 12 - *Caricetum magellanicae.* (Abbrev. for sites as in tab. 1).
- Caricetum magellanicae. *(Sigle per le stazioni come in tab. 1).*

the association level needs detailed comments, since there is much confusion about the syntaxonomy of *Trichophorum caespitosum* fens in central Europe. Although all plant ecologists agree in recognizing the wide ecological amplitude of *Trichophorum caespitosum*, which cannot hence be regarded as character species of any association, such fens were assigned to a number of associations and/or subassociations such as the *Bartsio-Caricetum nigrae* (BARTSCH & BARTSCH, 1940), the *Parnassio-Caricetum nigrae* (OBERDORFER, 1957), the *Tomenthypno-Trichophoretum* (YERLY, 1970), and the *Caricetum davallianae trichophoretosum caespitosi* (OBERDORFER, 1977).

DIERSSEN (1982) carefully analyzed a large amount of phytosociological tables of *Trichophorum caespitosum* fens in northern Europe which could be included in an association called *Drepanoclado revolventis-Trichophoretum cespitosi*. This association has *Trichophorum alpinum* and *Drepanocladus badius* as character species, the latter being exclusive of northern Europe. In addition, *Carex dioica* is regarded as a regional character species for Scandinavia. *Trichophorum caespitosum*, on the other hand, is only a differential species of the *Drepanoclado-Trichophoretum*. The *Trichophorum caespitosum* fens in central Europe have much in common with those in northern Europe and usually show a progressive reduction in the boreal floristic element as far as one proceeds southwards. All of those fens can be presumably included in one and the same association, even though this cannot be demonstrated in the absence of a comparative study.

The *Trichophorum caespitosum* fens in the Carnian Alps are mainly characterized by *Trichophorum alpinum* which occurs in 57% of the relevés (tab. 13) and has a clear preference for this vegetation type. Therefore, they can be assigned to the *Drepanoclado revolventis-Trichophoretum cespitosi*. The relevés include many character species of the allian-

Rel. n.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	%
Site	q	o	o	o	o	m	h	q	q	i	i	d	a	a	
Rel.area (sqm)	50	50	30	50	30	50	30	50	20	30	20	30	50	50	P
Cover (%) herb layer	80	90	100	90	100	95	90	95	95	90	80	90	90	95	r
Cover (%) moss layer	60	30	60	40	40	30	30	20	60	70	60	40	40	50	e
Rare species	2	5	-	1	-	5	7	12	18	4	6	5	5	5	s
N. of species	24	27	18	19	15	28	33	30	37	21	26	21	22	22	
ASSOCIATION															
Trichophorum alpinum	+	3	1	+		+		+	+		+				57
ALLIANCE															
Bartsia alpina	+	+	+	+		1	1	+	1	+	+	+	1	+	93
Campylium stellatum	3	2	3	2	1	+	1	1	1	1	1		2		86
Pinguicula vulgaris	1	+	+	+		+	+			1		+	+	+	71
Willemetia stipitata	+	+				1	1	2		+	2		1	1	64
Carex davalliana	+	+				1	1	+	1	+	+	+			64
Carex lepidocarpa		1			+	+	+	+		+	+	1	1		64
Tofieldia calyculata	+	+	+	+	+	+	+				+				57
Parnassia palustris		1	+	+		+	+	+	+						50
Carex oederi	1	+		+					+					1	36
Juncus alpino-articulatus	+										+	+	+	+	36
Selaginella selaginoides			+				+				+		+		29
Swertia perennis								+	+	+	+				29
Eleocharis quinqueflora	1			+	+										21
Triglochin palustre	+	+													14
Aster bellidiastrum							+		+						14
Carex dioica													+	+	14
Primula farinosa							+								7
Carex hostiana												+			7
Juncus triglumis														+	7
ORDER, CLASS															
Carex stellulata	+		+	+	+		1	1		1	1	+	1	1	79
Carex nigra	+					2	1	2	+	1	2	3	1	2	71
Carex rostrata	1	+	2	1	2		+		1			3	+	+	71
Drepanocladus revolvens	1	+	1	+	+	+	1			1	1	1			71
Eriophorum angustifolium	+	+	1	+	1	+				1			2	1	64
Calliergon trifarium		+	+	+	2					1	1	1			50
Calliergon sarmentosum						+	+			2	+	+			36
Menyanthes trifoliata		+	+	3								1			29
Scorpidium scorpioides			+		+	+					+				29
Drepanoclaudus exannulatus						1	+							2	21
Drosera anglica			+	+	+										21
Calliergon stramineum						+	+		+						21
Sphagnum warnstorfii	1									1					14
Sphagnum subsecundum							+								7
COMPANIONS															
Trichophorum caespitosum	3	3	4	3	3	3	3	3	3	4	3	1	1	1	100
Potentilla erecta	+	+	+	+	+	+	1	1	+	+	1	+	1	1	100
Molinia coerulea	+	1	+	+		+	+	1	1				2	+	71
Deschampsia caespitosa						+	+	+		+	+	+	+	+	57
Dactylorhiza fuchsii	+	+			+	+	+	+	+		r				57
Carex panicea						1	+	+	+				+	+	43
Valeriana dioica	+	+			+			+	+						36
Festuca rubra		+					+	+	+						29

Tab. 13 - *Drepanoclado revolventis-Trichophoretum cespitosi.* (Abbrev. for sites as in tab. 1).
- Drepanoclado revolventis-Trichophoretum cespitosi. *(Sigle per le stazioni come in tab. 1).*

Rel. n.	1	2
Site	e	e
Rel.area (sqm)	20	50
Cover (%) herb layer	95	90
Cover (%) moss layer	80	40
Rare species	5	10
N. of species	23	25
ASSOCIATION		
Angelica sylvestris	+	+
Cirsium palustre	+	+
ALLIANCE		
Myosotis scorpioides	+	
Crepis paludosa	+	
ORDER, CLASS		
Molinia coerulea	2	2
Succisa pratensis	+	+
Valeriana dioica	+	+
Lathyrus pratensis	+	
Filipendula ulmaria	+	
Juncus conglomeratus	+	
Equisetum palustre		+
Linum catharticum		+
COMPANIONS		
Carex davalliana	1	2
Carex hostiana	+	2
Potentilla erecta	+	+
Carex lepidocarpa	+	+
Plagiomnium elatum	+	+
Fissidens adiantoides	+	+
Campylium stellatum	+	+
Juncus alpino-articulatus	+	+

Tab. 14 - *Angelico-Cirsietum palustris.* (Abbrev. for sites as in tab. 1).
- Angelico-Cirsietum palustris. *(Sigle per le stazioni come in tab. 1).*

ce *Caricion davallianae*, among which *Bartsia alpina, Pinguicula vulgaris, Willemetia stipitata, Carex davalliana, Carex lepidocarpa, Tofieldia calyculata* and *Parnassia palustris* have a presence degree of at least 50%. There are, in addition, a number of character species of the order *Caricetalia nigrae* and of the class *Scheuchzerio-Caricetea nigrae* (see tab. 13).

The *Drepanoclado-Trichophoretum* develops on slightly sloping terrains, both on carbonate and on silicate rocks, and usually has a thin layer of peat. Hence, the mire water is always in contact with the mineral substrate and slowly flows either on the surface or through the peat. Due to the high solubility of the bicarbonate ion, such a flowing water is buffered also when the peat rests on silicate ground (tab. 18). However, some differentiation in the floristic composition of the *Drepanoclado-Trichophoretum* is determined by the geological substrate. The relevés made on carbonate ground, in fact, have *Carex dioica* as differential species (tab. 13, rel. 13-14) and show a certain affinity with the *Campylio-Caricetum dioicae*. There is some controversy on whether the latter association is really

										1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	3	3	%
Rel. n.	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	p
Site	n	n	n	e	e	e	e	e	m	m	m	n	o	n	q	n	n	n	o	o	m	m	n	o	m	m	m	h	b	b	a	r
Rel.area (sqm)	1	1	1	4	1	2	2	2	2	1	1	1	2	1	0	1	1	1	1	1	1	1	1	1	1	1	2	1	1	2	5	e
Cover (%x10) herb layer	6	6	6	6	6	7	6	6	7	6	8	5	6	7	6	4	6	6	7	5	5	4	6	8	6	6	8	6	7	9	9	s
Cover (%x10) moss layer	10	10	10	10	9	10	8	10	10	10	9	10	9	10	10	10	10	10	10	10	9	10	10	10	10	10	9	10	9	5	9	e
Rare species	-	2	-	-	-	-	3	1	3	2	-	1	1	5	4	-	-	1	1	1	-	-	1	2	2	1	3	3	4	3	10	n
N. of species		1	1			1	1		1	1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	2	c
	7	3	0	8	7	0	1	7	4	4	1	0	9	2	8	7	9	3	3	5	2	0	3	3	4	1	5	2	7	6	4	e
ASSOCIATION																																	
Sphagnum magellanicum	4	4	2	+	+	+	+	+	2	3	4	2	2	2			+	1	3	4			1	1		+							68
VAR. OF SPHAGNUM RUSSOWII																																	
Sphagnum russowii				1					3	1	2	4	3	3	5		1						+			1	1		2	1		45
SUB. SPHAGNETOSUM FUSCI																																	
Sphagnum fuscum																5	5	4															13
SUB. SPHAGNETOSUM NEMOREI																																	
Sphagnum nemoreum									1	2			1		+			+	3	2	5	5	4	4	5	5	4	5	3	2	1	58
VAR. OF LICHENS																																	
Cetraria islandica																													1	+	1	10
ALLIANCE, ORDER, CLASS																																	
Eriophorum vaginatum	+	+	+	+	1	1		+	+	+	+	+	1	2		+	2	2	1		+	1	+	1	1	2	2		+		81
Carex pauciflora	1	1	1	1		2	2		1	2	1	1	1	+	1	+	+	+		1	+	1	1	2	1	+	+					77
Vaccinium microcarpum	1	1	1							2	2	+				1	1	1		1			+	1		1						42
Polytrichum strictum					1							+		1					2	1	+	+	2				+		2			32
Andromeda polifolia		+							+				1			+	+	1			+	1	+	+								32
Sphagnum rubellum	1	2	3	5	4	5	4	5				+																				29
Mylia anomala		1								+		+						+			+				1				+		22
Calypogeia sphagnicola		+							+	+				+	+																	16
Drosera rotundifolia						+												+			+											10
COMPANIONS																																	
Calluna vulgaris			1	1	1	+	1		+	+	2	+	2		1				1	1	1			+	1	1	+	2	1	1	+	71
Vaccinium uliginosum	2	2	2									+	1		2	1	1	1	2	1	+		+	2	+	1	1	1		1	+	64
Potentilla erecta		+	+	+	+	+	+	+	2	1	+	+	+		+				+	+					+		1	1	1	1		64
Vaccinium vitis-idaea										1	+	+			1				+	+	+	+		+		+	1	1	2	1		45
Vaccinium myrtillus			+							+			+		+				+		1	+	+	+			+			1	+	39
Molinia coerulea				3	2	2	1	1					+							+		+							1	+	2	35
Carex nigra						+			1		+		+		1				1							1		1	+	+	+	35
Nardus stricta													+							+	1			1		+	+	1	2	2		29
Aulacomnium palustre		+	+				1						+		+		+	+						+		+						29
Homogyne alpina										+	+								+					+			+		+	+	1	26
Trichophorum caespitosum														2				+		1		+			+	1					+		22
Juniperus nana											+										1	+	+							1	+		19
Avenella flexuosa													+		+				1	+								+			+		19
Carex stellulata						1	1	2	+																	+							16
Melampyrum pratense ssp. paludosum														+	+								+	+			+						16

Tab. 15 - *Sphagnetum magellanici.* (Abbrev. for sites as in tab. 1).
- Sphagnetum magellanici. *(Sigle per le stazioni come in tab. 1).*

Rel. 1-8: subass. *typicum*, typical variant;
Rel. 9-15: subass. *typicum*, variant of *Sphagnum russowii*;
Rel. 16-18: subass. *sphagnetosum fusci*;
Rel. 19-28: subass. *sphagnetosum nemorei*, typical variant;
Rel. 29-31: subass. *sphagnetosum nemorei*, variant of lichens.

distinguished from the *Drepanoclado-Trichophoretum*, the only apparent difference between them consisting in the frequencies of some species (DIERSSEN, 1982).

3.2.4. Wet meadows

Angelico-Cirsietum palustris (AC, tab. 14). Corresponds to the vegetation of wet meadows, having *Angelica sylvestris* and *Cirsium palustre* as character species (BALATOVA-TULACKOVA, 1979). In the relevés there are only two character species of alliance (*Calthion palustris*), viz. *Myosotis scorpioides* and *Crepis paludosa*. By contrast, the set of character species of order (*Molinietalia caeruleae*) and class (*Molinio-Arrhenatheretea*) is well represented (see tab. 14).

The *Angelico-Cirsietum* develops at the mire margin at low-elevation sites, so that it was recorded at an only peatland lying just above 1000 m (Valpudia, tab. 1). Such wet meadows are established on mineralized peat and this reflects in the floristic composition including, besides plants typic of wet meadows, several fen species such as *Carex davalliana, Carex hostiana, Carex lepidocarpa, Campylium stellatum* and *Juncus alpino-articulatus* (tab. 14).

Unfortunately, no data are available on mire water chemistry in the habitats of the *Angelico-Cirsietum.*

3.2.5. *Sphagnum* carpets, hummocks and scrubs

Sphagnetum magellanici (SM, tab. 15). Corresponds to the vegetation of treeless *Sphagnum* hummocks having *Sphagnum magellanicum* as character species. The *Sphagnetum magellanici* is included in the alliance *Sphagnion magellanici*, the order *Sphagnetalia magellanici* and the class *Oxycocco-Sphagnetea* (tab. 3).

The set of species characterizing those syntaxa is well represented in the relevés (see tab. 15). Also frequent are the ericaceous shrubs (especially *Vaccinium* spp. pll. and *Calluna vulgaris*), listed among the companions.

Three main subgroups can be individuated in the *Sphagnetum magellanici*, corresponding to subassociations well known in the phytosociological literature (OBERDORFER, 1992). As clearly stated by DIERSSEN (1978), the main ecological factor responsible for the floristic variations occurring within this association is depth to water table. Due to the sampling strategy adopted, water-table depths could not be periodically monitored in this study. However, experimental data collected at some peatlands in the southeastern Alps showed significant differences in water-table depth among the different subassociations of the *Sphagnetum magellanici* (GERDOL & TOMASELLI, 1991). Based on the results of that study, the phytosociological table was ordered according to a presumable gradient of increasing depth to water table. The *Sphagnetum magellanici typicum* (tab. 15, rel. 1-15)

corresponds to low hummocks where the character species *Sphagnum magellanicum* clearly finds its ecological optimum. Two smaller groups could be distinguished within the *Sphagnetum magellanici*, the one (tab. 15, rel. 1-8) having *Sphagnum rubellum* as most abundant peat moss of the sect. *Acutifolia*, and the other (tab. 15, rel. 9-15) *Sphagnum russowii*. They are regarded as variants. The variant of *Sphagnum russowii* is presumably linked to habitats richer in nutrients, but experimental evidence in this respect is still poor. The subassociation *sphagnetosum fusci* (tab. 15, rel. 16-18), having *Sphagnum fuscum* as differential species, and even more the subassociation *sphagnetosum nemorei* (tab. 15, rel. 19-31), differentiated by *Sphagnum nemoreum*, are linked to higher hummocks. Within the latter, a variant of lichens (tab. 15, rel. 29-31) could be distinguished, which typically covers the arid top surface of the highest hummocks. The relevés of that variant are poor in bog plants, the field layer mainly consisting in xerophilous species such as *Vaccinium vitis-idaea* and *Nardus stricta*. Also the cover degree of mosses is considerably reduced (tab. 15).

The *Sphagnetum magellanici* is widespread in the wetlands of the Carnian Alps and lacks only at the peatlands located at the highest elevations. Mire water in the habitats of the *Sphagnetum magellanici* has on the average a low pH as well as a low electrical conductivity (tab. 18). However, both means have an unusually high standard error thus indicating a wide range of nutrient availability.

Eriophoro-Trichophoretum cespitosi (ET, tab. 16). Corresponds to the vegetation of flat carpets having *Sphagnum compactum* often associated with pleurocarpous mosses, as the most abundant species in the bottom layer and *Trichophorum caespitosum* as the dominant species in the field layer. Whereas the latter cannot be regarded as character species for the reasons discussed above, *Sphagnum compactum* is ecologically centred in the *Eriophoro-Trichophoretum* all over central Europe even though it is more abundant in the bog vegetation of western Europe (DIERSSEN, 1978). Accordingly, *Sphagnum compactum* can be considered as a regional character species of the *Eriophoro-Trichophoretum*. This association is included in the same high-rank syntaxa as the *Sphagnetum magellanici* (tab. 3) due to the presence of several character species of alliance, order and class, of which the most frequent are *Carex pauciflora, Eriophorum vaginatum* and *Sphagnum russowii*.

There are, by contrast, remarkable differences between *Sphagnetum magellanici* and *Eriophoro-Trichophoretum* as far as the companions are concerned, the set of companions in the latter being much wider and including a number of species transgressive from fens which are rare or even absent in the former, such as *Carex stellulata, Carex nigra,*

Tab. 16 - *Eriophoro-Trichophoretum cespitosi*. (Abbrev. for sites as in tab. 1).
- Eriophoro-Trichophoretum cespitosi. *(Sigle per le stazioni come in tab. 1).*
Rel. 1-14: typical variant;
Rel. 15-19: variant of *Swertia perennis*.

Rel. n.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	%
Site	o	o	n	g	g	l	i	i	i	a	a	a	b	b	m	m	o	o	p	
Rel.area (sqm)	50	50	50	10	20	20	2	50	20	20	30	30	30	25	30	20	30	50	20	p
Cover (%) herb layer	95	85	90	80	70	70	70	80	85	95	95	95	95	95	80	80	95	90	100	r
Cover (%) moss layer	70	50	70	70	90	80	90	50	60	30	10	20	60	50	10	40	60	70	80	e
Rare species	7	4	4	1	2	1	4	8	2	4	1	8	6	4	4	-	8	5	8	s
N. of species	33	25	25	20	26	19	20	33	22	20	17	22	30	21	23	17	30	31	28	
ASSOCIATION																				
Sphagnum compactum (loc.)	+	2	+	2	1	1		1	+	1	+	+	2	2						68
VARIANT OF SWERTIA PERENNIS																				
Swertia perennis															+		+	+		16
ALLIANCE, ORDER, CLASS																				
Carex pauciflora	2	2	+	2	1		1	+		+						1		+		53
Eriophroum vaginatum	+	+					1	1	1	+	+				+		+	+		53
Sphagnum russowii			3	2	2		1	1							1	1				37
Drosera rotundifolia		+								+	+						+	+	+	31
Sphagnum magellanicum	1	1			2		1													21
Sphagnum nemoreum									1	1				1						16
Sphagnum rubellum	1	+											+							16
Andromeda polifolia	+	+																+		16
Sphagnum subnitens								1					+							10
Polytrichum strictum						+		+												10
Sphagnum fuscum							3													5
Calypogeia sphagnicola		+																		5
Vaccinium microcarpum																		+		5
COMPANIONS																				
Trichophorum caespitosum	2	2	2	1	1	1	2	4	3	4	4	4	3	4	4	3	3	2	3	100
Potentilla erecta	+		1	+	3	+	1	+	1	1	+	+	1	2	+	+	+	+	+	95
Carex stellulata	2	+	1	2	1	1	1	1	1	1	2	1	1	1	1	+	+		+	95
Carex nigra	1	+	1	1	1	2	1	1	1	+		1	1	1	+	+	+	+	1	95
Eriophorum angustifolium	+			1	+	+			+	1	1	1	1	+	+	+	1	+	+	79
Molinia coerulea	1	1	1	1	+					+	+	+	2	1	+	+	1	2		67
Bartsia alpina	+		+					+	+	+	+	2	+		+		+	+	+	63
Homogyne alpina			1		+	1		1	1	+	+	+	+	1				+	+	63
Sphagnum subsecundum	1	+		+					3		+		+		1	2	1	1	2	58
Pinguicula vulgaris	+	+	+	+	+						+	+				+	+	+	+	58
Aulacomnium palustre	1		2			2	+	+							+	+	+	+	+	53
Willemetia stipitata	r				+			+	1	+	+	1	1					+	2	53
Nardus stricta	+		+	1	1	1	1	1	1				+	1						53
Carex rostrata	1	1			+					+	1		1		+	+	+	1		53
Viola palustris	+	+	+	+	1			+	+				1		+			+		53
Calliergon stramineum	+	+	+		+	+	1		+						+			+	1	47
Scapania irrigua	+	+	+	+								+	1		+			+		42
Luzula sudetica	+		+		+	+		+	+				+						+	42
Parnassia palustris	+		+								+		+		+	+	+	+		42
Calluna vulgaris				+				+		+			+	+			+		+	37
Sphagnum fallax						2	2								+	+		+	2	31
Juncus filiformis			+	1	+	1						+		+						31
Festuca rubra				+	+			+					+	+			+			31
Selaginella selaginoides						+		+	+						+		+	+		31
Sphagnum flexuosum	2	1			2											+	+			26
Drepanocladus exannulatus					1						+		+	1		+				26
Vaccinium vitis-idaea			+	+			+	1						+						26
Dicranum scoparium	+	+	+				+	+												26
Carex oederi				+		+						+				+	+			26
Sphagnum warnstorfii		1															3	3	2	21
Sphagnum centrale					1												+	+	+	21
Lephozia wenzelii						+		+	+					1						21
Deschampia caespitosa					+				+				+						+	21
Leontodon helveticus						+	+	+	+											21
Anthoxanthum odoratum								+					+	+					+	21

Rel. n.	1	2	3	4	5	6	%
Site	n	n	o	o	m	g	
Rel.area (sqm)	10	10	20	10	20	20	P
Cover (%) shrub layer	90	90	90	95	90	50	r
Cover (%) herb layer	70	80	75	90	80	90	e
Cover (%) moss layer	70	60	60	70	70	90	s
Rare species	-	3	3	3	-	4	
N. of species	16	19	24	21	14	21	
ASSOCIATION							
Pinus mugo	5	5	5	5	5	3	100
Melampyrum pratense ssp.paludosum (d)			+		+	+	50
ALLIANCE, ORDER, CLASS							
Sphagnum magellanicum	+	1	2	+	+	3	100
Eriophorum vaginatum	+	+	1	1	1	1	100
Sphagnum russowii	2	2	2	3		3	83
Carex pauciflora	+	+		+	+	3	83
Polytrichum strictum	1		+	+	+	1	83
Sphagnum nemoreum	1	1	1		4		67
Vaccinium microcarpum	+		+	+			50
Calypogeia sphagnicola			+		+		33
Sphagnum rubellum	+						17
Andromeda polifolia			+				17
Sphagnum compactum			+				17
Sphagnum angustifolium				+			17
Mylia anomala					+		17
Drosera rotundifolia						+	17
COMPANIONS							
Vaccinium myrtillus	3	3	3	3	3	1	100
Vaccinium uliginosum	1	+	2	2	1		83
Vaccinium vitis-idaea	+	+	1	1		2	83
Sphagnum fallax	+	1	1	+		1	83
Dicranum scoparium	+	+	+	1	+		83
Pleurozium schreberi	+	+	1	2			67
Picea excelsa	1	+			1	1	67
Calluna vulgaris		+	+	+		1	67
Carex nigra		+	+	+		+	67
Rhododendron ferrugineum				1	1	1	50
Potentilla erecta		+				1	33
Molinia coerulea			+			1	33
Calypogeia azurea			+	+			33

Tab. 17 - *Pino mugo-Sphagnetum.* (Abbrev. for sites as in tab. 1).
- Pino mugo-Sphagnetum. *(Sigle per le stazioni come in tab. 1).*

Eriophorum angustifolium, Bartsia alpina, Sphagnum subsecundum, Pinguicula vulgaris, Willemetia stipitata and others. Most of those species are typical components of the *Drepanoclado-Trichophoretum* fens (see tab. 13). This justifies the floristic resemblance between *Drepanoclado-Trichophoretum* and *Eriophoro-Trichophoretum*, clearly resulting

from the dendrogram (fig. 2). In addition, both associations have *Trichophorum caespitosum* as dominant species. These are the reasons why the whole *Trichophorum caespitosum*-dominated mire vegetation was anciently grouped into one and the same association named *Trichophoretum cespitosi* (KOCH, 1928) which cannot be further retained owing to the lack of character species. Evidence from several studies shows that the peatland vegetation in central Europe having *Trichophorum caespitosum* as dominant species can be split into two associations thriving in different kinds of habitat. First, sloping fens corresponding to the *Drepanoclado revolventis-Trichophoretum cespitosi*. The distributional area of this association probably extends from northern Scandinavia to the Alps (see above). Second, flat *Sphagnum* carpets corresponding to the *Eriophoro-Trichophoretum cespitosi* in central Europe (OBERDORFER, 1992) and to the *Trichophoro-Sphagnetum compacti* in northern Europe (DIERSSEN, 1982).

No doubt all of the regional associations and subassociations defined in different territories in central Europe, showing the common dominance of *Trichophorum caespitosum* as well as the presence of several *Oxycocco-Sphagnetea* species both in the field and in the bottom layer can be substantially identified with the *Eriophoro-Trichophoretum.*

These are, for instance, the *Caricetum nigrae trichophoretosum* (BRAUN-BLANQUET, 1948-49), the *Sphagno-Trichophoretum* (YERLY, 1970) and the *Carici echinatae-Trichophoretum caespitosi* (RYBNICEK & RYBNICKOVA, 1977). It can also be questioned whether a real difference does exist between the *Eriophoro-Trichophoretum cespitosi* and the *Trichophoro-Sphagnetum compacti*, although the latter is richer in boreal species occurring only rarely (*Betula nana*) or not at all (*Rubus chamaemorus*) in central Europe. A comparative analysis of phytosociological data is required to solve this question.

Two subgroups can be distinguished within the *Eriophoro-Trichophoretum cespitosi* in the Carnian Alps, which can be interpreted as variants. The typical variant (tab. 16, rel. 1-14) lacks any differential species, whereas the variant of *Swertia perennis* (tab. 16, rel. 15-19) includes more species typic of rich fens, and shows therefore the closest affinity with the *Drepanoclado-Trichophoretum. Swertia perennis* can be considered as the better differential species for this variant. The *Eriophoro-Trichophoretum* occurs at a number of sites, especially in the upper subalpine belt. It often develops in close contact with the *Drepanoclado-Trichophoretum* rich fens on very slightly inclined terrains (2‰), where these two associations may be dynamically related. The *Eriophoro-Trichophoretum* also develops on mire plateaux, particularly in the areas where peat does not accumulate. Experimental data (GERDOL, unpublished) showed that the growth rate of *Sphagnum compactum* is much slower than those of all other *Sphagna*. The habitat in the *Eriophoro-Trichophoretum* usually is wetter than in the *Sphagnetum magellanici*, although it may undergo considerable desiccation in arid periods. Mire water has a moderately low pH and is poor in nutrients (tab. 18).

	pH	El. conductivity (µS cm^{-1})
Cratoneuretum falcati	7.69±0.11	183±2
Comm. of *Cardamine amara*	7.54	356
Bryo-Philonotidetum seriatae	6.85	74
Caricetum rostratae	6.50	153
Comm. of *Carex juncella*	6.81±0.31	111±62
Caricetum limosae typicum	4.36±0.48	5±7
C.l. scorpidietosum	5.74	89
Eriophoretum scheuchzeri	5.54±0.32	29±10
Caricetum nigrae	5.69±0.55	31±15
Caricetum magellanicae	-	-
Drepanoclado-Trichophoretum	6.24±0.75	179±143
Angelico-Cirsietum	-	-
Sphagnetum magellanici	4.59±1.12	19±24
Eriophoro-Trichophoretum	4.75±0.16	18±7
Pino mugo-Sphagnetum	4.15±0.20	11±10

Tab. 18 - Mean values (± S.E.) of pH and electrical conductivity of mire water in the vegetation types.
- *Valori medi (± errore standard) di pH e conducibilità elettrica dell'acqua in alcuni tipi di vegetazione.*

	pH	El. cond.	Na^+	K^+	Ca^{2+}	Mg^{2+}
Fens	6.24±0.75	179±143	51±28	62±76	1447±1102	85±19
Laggs & springs	7.09±0.56	183±106	93±73	19±16	1238±470	439±429
Bog scrubs	4.15±0.20	11±10	32±22	10±2	70±34	47±39
Sphagnum carpets	4.79±0.15	17±4	63±69	14±11	78±35	45±19
Hollows	4.36±0.48	5±8	8±7	5±2	45±32	20±9

Tab. 19 - Mean values (± S.E.) of pH, electrical conductivity (as µS cm^{-1}) and of cation concentrations (as µeq L^{-1}) in mire water in the vegetational formations.
- *Valori medi (± errore standard) di pH, conducibilità elettrica (in µS cm^{-1}) e concentrazioni cationiche (in µeq L^{-1}) nell'acqua delle principali formazioni vegetazionali.*

Pino mugo-Sphagnetum (PS, tab. 17). Corresponds to the vegetation of prostrate pine scrubs having *Pinus mugo* as character species, always with a high cover degree, and *Melampyrum pratense* ssp. *paludosum* as differential taxon. The *Pino mugo-Sphagnetum* represents a distinctive feature of mires in the mountainous groups of central Europe (KRISAI, 1965; NEUHÄUSL 1972; KAULE 1974a, 1974b; PEDROTTI, 1978; GERDOL & PICCOLI, 1982; DIERSSEN & DIERSSEN, 1984; FELDMEYER-CHRISTE, 1990; GERDOL & TOMASELLI, 1991; OBERDORFER, 1992). Such a vegetation is remarkably uniform all over its distributional area so that its syntaxonomical characterization does not meet with any heavy obstacle (NEUHÄUSL, 1969). The *Pino mugo-Sphagnetum* belongs to the same high-rank units as the *Sphagnetum magellanici*, viz. *Sphagnion magellanici*, *Sphagnetalia magellanici* and *Oxycocco-Sphagnetea*, of which several character species commonly occur in the relevés. All of them are in common with open *Sphagnum* hummocks (see tabs. 15 and 17). Among the companions there are a number of species, such as *Vaccinium myrtillus, Vaccinium uliginosum, Vaccinium vitis-idaea, Dicranum scoparium, Picea excelsa* and *Rhododendron ferrugineum*, transgressive from the class *Vaccinio-Piceetea*.

The *Pino-Sphagnetum* occupies raised habitats in mire sectors bearing an acidic water extremely poor in electrolytes (tab. 18).

3.3. Hydrochemistry

Mire water shows broad ranges in the concentrations of all major cations as well as pH and electrical conductivity (tab. 19). The variables included in the stepwise procedure of multiple discriminant analysis at a significance threshold of 0.01 are only pH and calcium. They account, however, for similar trends in electrical conductivity and magnesium concentrations, as shown by the high correlation coefficients between those variables (tab. 20).

	El. cond.	Sodium	Potassium	Calcium	Magnesium
pH	0.82*	0.39	0.25	0.81*	0.65
El. cond.		0.50	0.58	0.89*	0.72*
Sodium			0.32	0.26	0.69*
Potassium				0.55	0.13
Calcium					0.41

Tab. 20 - **Correlation coefficients between hydrochemical variables. (* = P<0.01)**
- ***Coefficienti di correlazione fra le variabili idrochimiche.***

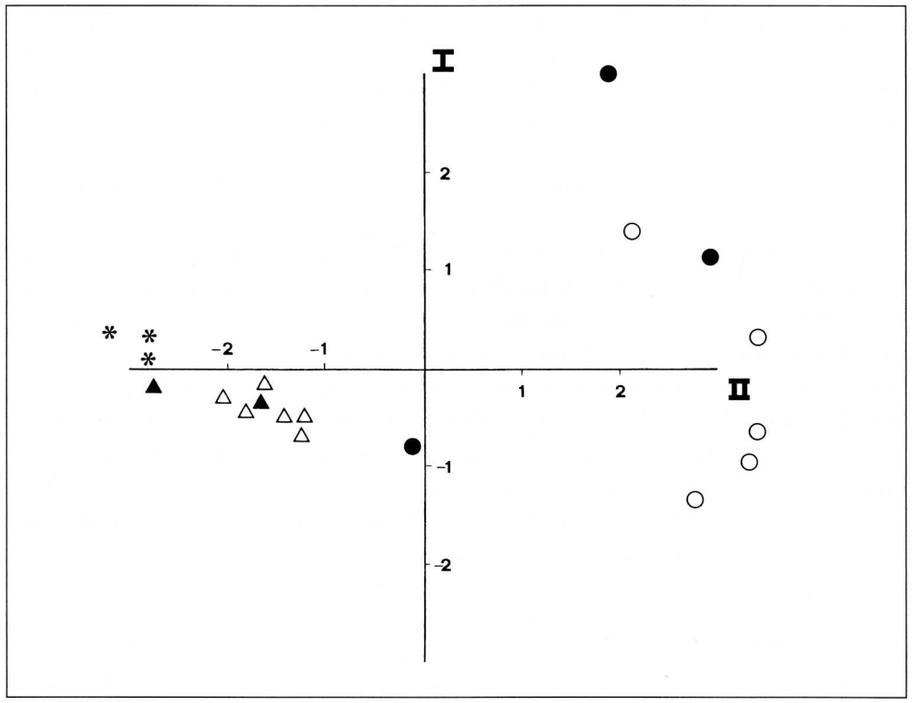

Fig. 3 - Ordination of the sample plots (grouped as in fig. 4), based on the first two discriminant scores.
- *Ordinamento dei rilievi (raggruppati come in fig. 4) lungo i primi due assi dell'analisi discriminante.*

The canonical correlation of the first discriminant function largely exceeds that of the second one (tab. 21), thus pointing to the former as the main direction of variation in mire-water chemistry. The ordination of the sample plots, after grouping them into five sets corresponding to the main vegetational formations, along the first discriminant axis (fig. 3) reflects a gradient of increasing pH in the sense: bog scrubs → hollows → *Sphagnum* carpets → fens → laggs and springs. The Ca^{2+} concentrations have a comparable trend (see tab. 19).

I function	0.95
II function	0.54

Tab. 21 - Canonical correlations of the first two discriminant functions.
- *Correlazioni canoniche delle prime due funzioni discriminanti.*

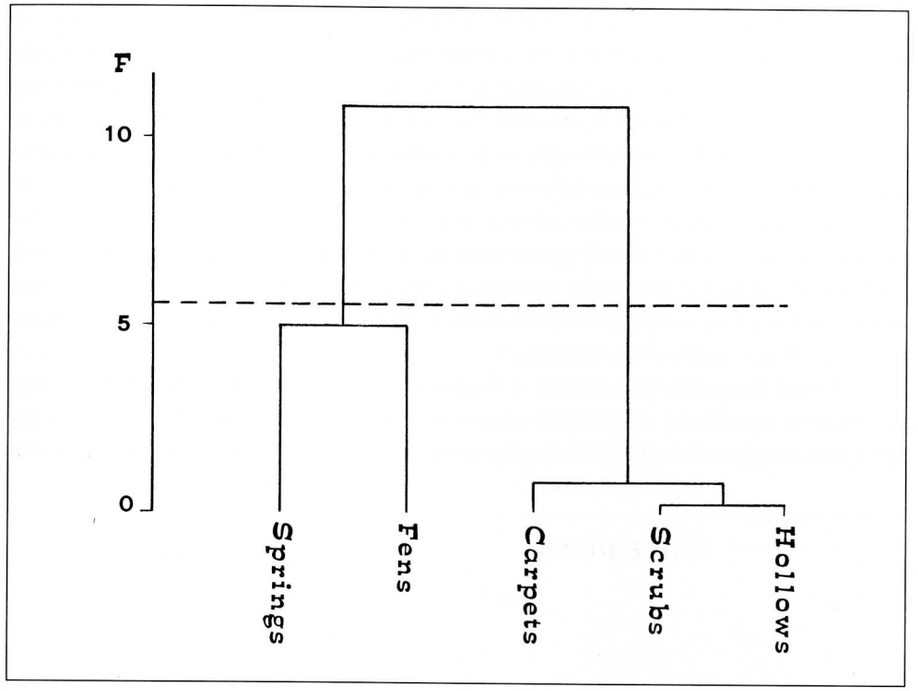

Fig. 4 - Classification dendrogram of the main vegetational formations, by single linkage clustering based on the F values resulting from the multiple discriminant analysis.
- *Dendrogramma di classificazione delle principali formazioni vegetazionali ottenuto con il metodo del legame singolo basato sui valori di F risultanti dall'analisi discriminante.*

When clustering those five formations (fig. 4), two main groups are separated at a significance level of 0.01, viz. (i) that of nutrient-rich vegetation, including springs, laggs and fens with subneutral water rich in calcium; and (ii) nutrient-poor vegetation, including *Sphagnum* carpets, bog scrubs and hollows with acidic water poor in calcium. Springs and laggs are discriminated from fens only at the confidence level of 0.05 (fig. 4).

3.4. Mire typology

The variation in the major hydrochemical variables (viz. pH and calcium concentration, see above), as well as the vegetational patterns detected along transects at four selected sites, served as a useful basis for attempting a classification of those mires, in the absence of hydrotopographical data. As discussed above, the four sites selected for this purpose can be regarded as a representative sample of mire sites in the study area.

At Valle di Aip wetland vegetation develops at two different levels, the one on a nearly flat terrace and the other on the sloping thalweg (fig. 5). The former can be regarded as a poor fen sheltering a mosaic of *Sphagnum* carpets (*Eriophoro-Trichophoretum cespitosi*) and shallow pools (*Caricetum limosae typicum*). Even if the mire surface is hardly raised above the surrounding terrain, the low pH as well as the low electrical conductivity (fig. 5) indicate a poor influence of mineral water. In contrast, the latter is a rich fen steadily influenced by carbonate-rich water and has the *Drepanoclado revolventis-Trichophoretum cespitosi* as the typical association of sloping fens. There are also some pools colonized by the *Caricetum rostratae*, in which water often stagnates, while on the more inclined terrain water flows on the surface. Those latter areas are covered by spring-tufa vegetation (*Cratoneuretum falcati*).

Most of the gentle slopes south of Nemes Alm are covered by mire vegetation (fig. 6). There is a profound difference between the nearly flat upslope sector covered by *Sphagnum* carpets (*Eriophoro-Trichophoretum*) and scrubs (*Pino-Sphagnetum*) and the

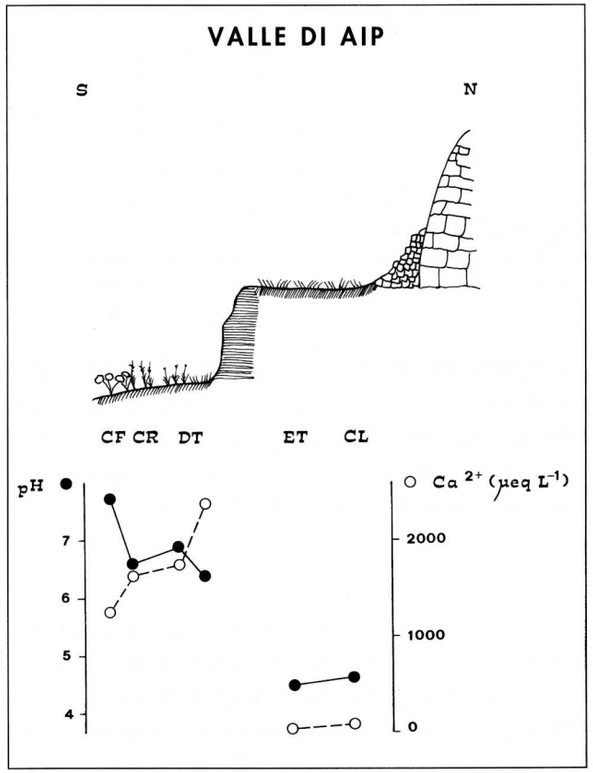

Fig. 5 - Schematic transect (not in scale) of vegetation and hydrochemistry at Valle di Aip.
- *Transetto schematico (non in scala) della vegetazione e del chimismo delle acque nella Valle di Aip.*

more inclined downslope sector covered by a rich-fen vegetation (*Drepanoclado-Trichophoretum*). Such a floristic differentiation finds a good correspondence in the hydrochemical transect. Mire water is acidic and nutrient-poor in the *Eriophoro-Trichophoretum* and especially in the *Pino-Sphagnetum*, only slightly acidic and fairly nutrient-rich in the *Drepanoclado-Trichophoretum* (fig. 6). The peatland at Nemes Alm can be regarded as a transitional mire (Zwischenmoor; PAUL & LUTZ, 1941), showing a broad-scale pattern of rich fen, poor fen and bog scrub.

The peatland at Forcella Lavardet is mostly covered by a *Sphagnum*-rich vegetation forming a raised bog scrub (*Pino-Sphagnetum*) in the eastern sector and a flat carpet (*Eriophoro-Trichophoretum*) in the western sector, both having water with hydrochemical features quite similar to those in the upslope sector at Nemes Alm. Only a narrow inclined area between those two sectors is influenced by mineral water flowing on the surface and covered by the community of *Cardamine amara* (fig. 7). Also this peatland can, therefore, be included in the large category of transitional mires. It shows, however, a much smaller range of variation than Nemes Alm for lacking any rich-fen vegetation.

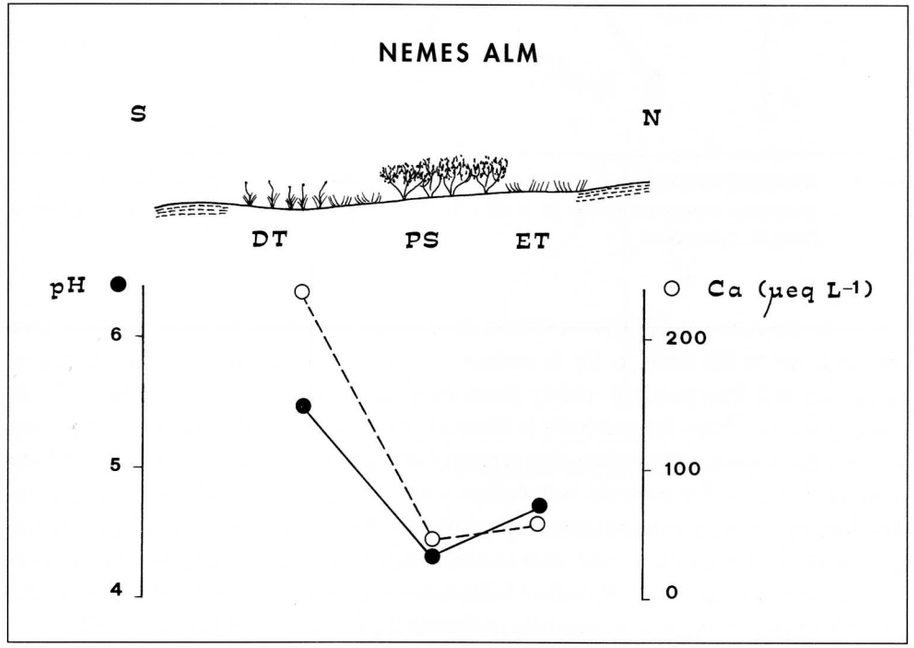

Fig. 6 - Schematic transect (not in scale) of vegetation and hydrochemistry at Nemes Alm.
- *Transetto schematico (non in scala) della vegetazione e del chimismo delle acque all'Alpe di Nemes (Nemes Alm).*

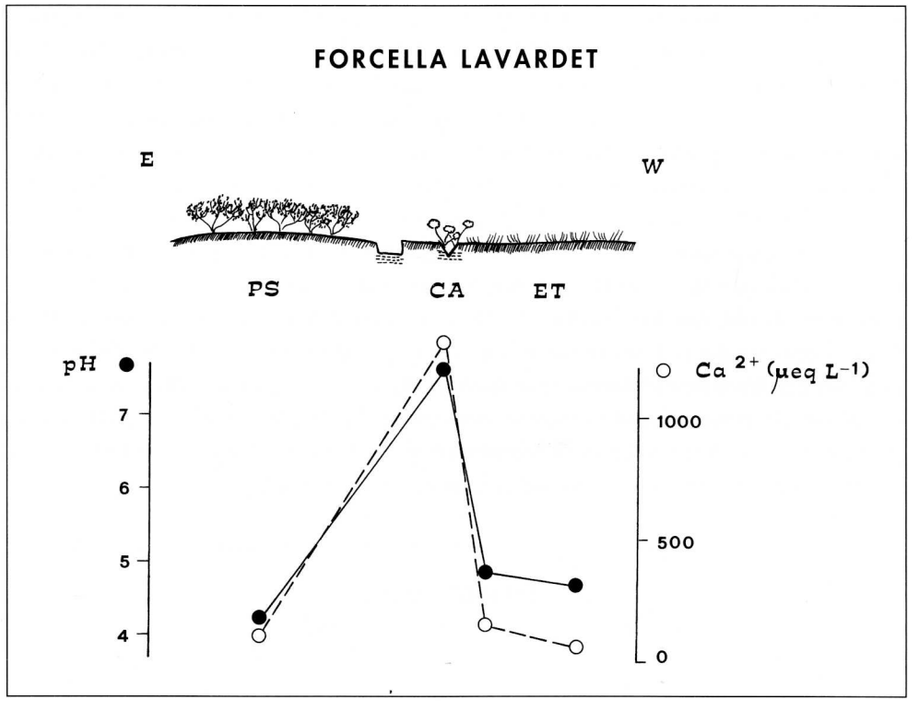

Fig. 7 - Schematic transect (not in scale) of vegetation and hydrochemistry at Forcella Lavardet.
- *Transetto schematico (non in scala) della vegetazione e del chimismo delle acque a Forcella Lavardet.*

The peatland west of Casera Coltrondo certainly represents the most complex mire site analysed in this study as far as surface-morphology, hydrochemistry and vegetation are concerned. This peatland mainly develops on a flat saddle of glacial origin (fig. 8, transect below). Here, the peat body is distinctly raised above the surrounding terrain and covered by a mosaic of prostrate pine scrubs (*Pino-Sphagnetum*) and hollows (*Caricetum limosae typicum*). The marginal belt shelters a swamp lagg (community of *Carex juncella*). The mire further extends downslope onto one of the gently inclined sides. Here the peat body is much flatter and covered by treeless *Sphagnum* carpets (*Eriophoro-Trichophoretum*) and low hummocks (*Sphagnetum magellanici*). Also this latter mire sector is bordered by a narrow swamp lagg sheltering the community of *Carex juncella*.

The peatland west of Casera Coltrondo can be included in the category of ombrosoligenous saddle-mires (ombrosoligene Sattelmoore; KAULE, 1973). Such peatlands have several features in common with transitional mires and especially with ombrosoligenous

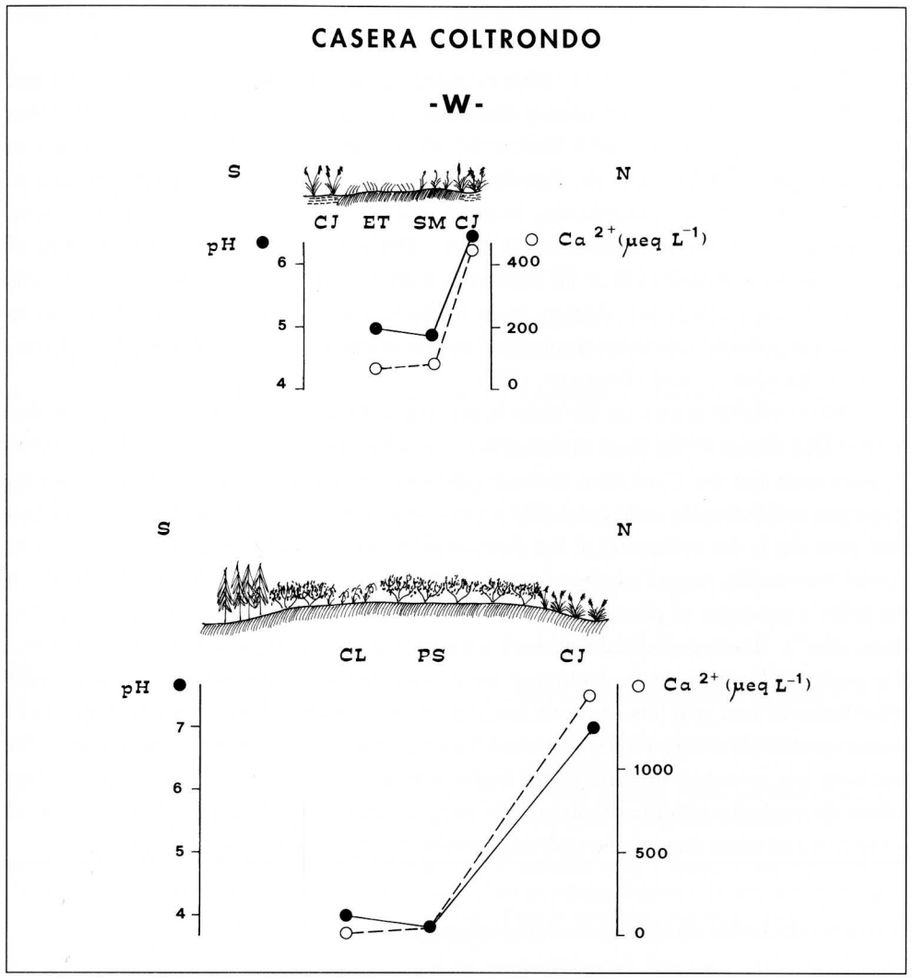

Fig. 8 - Schematic transects (not in scale) of vegetation and hydrochemistry at the peatland west of Casera Coltrondo.
- *Transetti schematici (non in scala) della vegetazione e del chimismo delle acque nella torbiera a Ovest di Casera Coltrondo.*

slope mires, all of those mire types comprising one or more ombrotrophic sectors together with areas covered by poor fens. The most distinctive character of saddle mires in the Alps probably consists in the regular occurrence on the ombrotrophic mire sectors of prostrate pine bog scrubs (occasionally also of Norway spruce forests) and bog hollows, forming

either a mosaic or a concentric pattern in which the scrubs typically occupy the peripheric belt and the hollows the wetter central area.

There frequently exist appreciable vegetational differences between bog sectors and poor-fen sectors, but hydrochemistry does not show sharp differences from each other although the bog sectors usually have water somewhat more acidic and even poorer in nutrients than poor fens (fig. 8). Threshold values of any hydrochemical variable can be hardly established for discriminating between bogs and poor fens, as had been for long attempted by Scandinavian workers (WITTING, 1947). In fact, there is a broad range of overlap in the concentration of all cations in waters collected from bogs and poor fens (MALMER et al., 1992). In addition, most hydrochemical variables are often subject to remarkable periodic variations determined by the seasonal activity of plants and to precipitation chemistry as well (DAMMAN, 1986).

More reliable seems, on the other hand, a discrimination based on vegetational characteristics. Some of the plant communities described in this study, especially the *Pino-Sphagnetum* and the *Caricetum limosae typicum,* are nearly exclusive of ombrogenous bogs and ombrotrophic mire areas. Even more predictive for discriminating between bog and poor fen is the evaluation of the distributional patterns of single plant species. Many useful data in this respect can be drawn from the classic paper of DU RIETZ (1954) which includes a catalogue of plants exclusive of fen habitats in Scandinavia (the so-called "fen indicators"). However, subsequent work showed that such fen indicators can have only a regional validity since their ecological niche may undergo some variations within their distributional area, and this can even imply a remarkable shift in the ecological optima of some species (ALETSEE, 1967). There is so far an apparent lack of experimental work for defining fen indicators in mires of the alpine region. To this aim, we should acquire data about the ecological profile of mire plants along the main hydrological and hydrochemical gradients and relate them to the hydrotopographical characteristics of mire sites.

Appendix - List of the rare species in the phytosociological tables

Tab. 4 - ***Cratoneuretum falcati***

Rel. 1: *Plagiomnium elatum, Veratrum album, Anthriscus* sp.
Rel. 2: *Pinguicula vulgaris, Juncus triglumis, Carex ferruginea, Carex frigida, Polygonum viviparum.*
Rel. 3: *Equisetum palustre, Bartsia alpina, Poa alpina, Allium schoenoprasum* ssp. *sibiricum, Aster bellidiastrum.*

Tab. 6 - ***Bryo-Philonotidetum seriatae***

Rel. 1: *Luzula sudetica, Potentilla erecta, Pinguicula vulgaris, Bartsia alpina, Eriophorum angustifolium, Juncus filiformis.*
Rel. 2: *Festuca rubra, Carex stellulata, Carex panicea, Juncus alpino-articulatus, Epilobium anagallidifolium, Agrostis canina.*

Rel. 3: *Blysmus compressus, Anthriscus* sp, *Veratrum album, Veronica beccabunga, Anthoxanthum odoratum, Equisetum palustre.*

Tab. 7 - ***Caricetum rostratae***

Rel. 3: *Carex panicea, Deschampsia caespitosa, Caltha palustris* ssp. *laeta, Cardamine rivularis, Galium palustre, Silene alpestris, Epilobium palustre, Bryum pseudotriquetrum, Cratoneuron commutatum* var. *falcatum.*

Tab. 11 - ***Caricetum nigrae***

Rel. 1: *Polytrichum commune.*
Rel. 3: *Sphagnum teres, Sphagnum molle, Cardamine rivularis, Galium palustre, Bryum pseudotriquetrum, Poa alpina, Epilobium anagallidifolium.*
Rel. 4: *Sphagnum fallax* (cl.), *Pinguicula vulgaris* (cl.), *Selaginella selaginoides* (cl.), *Carex pauciflora, Sphagnum nemoreum, Calypogeia sphagnicola, Dicranum scoparium* var. *paludosum, Cephaloziella elachista, Climacium dendroides.*
Rel. 5: *Swertia perennis* (cl.), *Trichophorum alpinum* (cl.), *Crepis paludosa, Valeriana dioica, Galium palustre, Epilobium palustre, Anthoxanthum odoratum.*
Rel. 6: *Caltha palustris* ssp. *laeta, Epilobium palustre, Homogyne alpina, Anthoxanthum odoratum, Rhinanthus* sp., *Drepanocladus fluitans* (cl.).
Rel. 7: *Caltha palustris* ssp. *laeta, Poa alpina, Rhinanthus* sp.
Rel. 8: *Carex oederi* (cl.), *Homalothecium nitens* (cl.), *Carex panicea, Hypnum pratense, Bryum pseudotriquetrum, Homogyne alpina, Dactylorhiza fuchsii.*

Tab. 13 - ***Drepanoclado revolventis-Trichophoretum cespitosi***

Rel. 1: *Pedicularis palustris* (cl.), *Equisetum palustre.*
Rel. 2: *Crepis aurea, Carex paniculata, Polygala* sp., *Drosera rotundifolia, Cirsium palustre.*
Rel. 4: *Odontoschisma elongatum.*
Rel. 6: *Calluna vulgaris, Luzula sudetica, Anthoxanthum odoratum, Alchemilla* gr. *vulgaris, Campanula scheuchzeri.*
Rel. 7: *Agrostis canina* (cl.), *Dicranum scoparium* var. *paludosum, Calluna vulgaris, Scapania paludicola, Homogyne alpina, Luzula sudetica, Allium schoenoprasum* ssp. *sibiricum.*
Rel. 8: *Calliergonella cuspidata, Plagiomnium elatum, Equisetum palustre, Anthoxanthum odoratum, Alchemilla* gr. *vulgaris, Campanula scheuchzeri, Equisetum sylvaticum, Cirsium helenioides, Rhinanthus* sp., *Climacium dendroides, Ranunculus acris, Briza media.*
Rel. 9: *Carex ferruginea, Calluna vulgaris, Aulacomnium palustre, Arnica montana, Galium palustre, Anthoxanthum odoratum, Sphagnum nemoreum, Veratrum album, Alchemilla* gr. *vulgaris, Campanula scheuchzeri, Carex paniculata, Sphagnum centrale, Trollius europaeus, Ranunculus acris, Sphagnum fallax* (cl.), *Lotus alpinus, Briza media, Polygala* sp.
Rel. 10: *Hypnum pratense, Cratoneuron decipiens, Allium schoenoprasum* ssp. *sibiricum, Odontoschisma elongatum.*
Rel. 11: *Hypnum pratense, Caltha palustris* ssp. *laeta, Cratoneuron commutatum* var. *falcatum, Allium schoenoprasum* ssp. *sibiricum, Epilobium anagallidifolium, Homalothecium nitens* (cl.).
Rel. 12: *Equisetum palustre, Caltha palustris* ssp. *laeta, Bryum pseudotriquetrum, Cratoneuron commutatum* var. *falcatum, Epilobium anagallidifolium.*
Rel. 13: *Hypnum pratense, Fissidens adiantoides, Euphrasia rostkoviana, Trifolium pratense, Nardus stricta.*
Rel. 14: *Fissidens adiantoides, Trifolium pratense, Equisetum fluviatile* (cl.), *Blysmus compressus, Polygonum viviparum.*

Tab. 14 - ***Angelico-Cirsietum palustris***

Rel. 1: *Carex nigra, Calliergonella cuspidata, Senecio cacaliaster, Carex panicea, Scrophularia nodosa.*
Rel. 2: *Hypnum pratense, Homalothecium nitens, Menyanthes trifoliata, Scapania paludicola, Tofieldia calycu-*

lata, Parnassia palustris, Eriophorum latifolium, Trichophorum alpinum, Pinguicula vulgaris, Riccardia pinguis.

Tab. 15 - ***Sphagnetum magellanici***

Rel. 2: *Calliergon stramineum, Sphagnum fallax.*
Rel. 7: *Arnica montana, Carex magellanica, Scapania paludicola.*
Rel. 8: *Menyanthes trifoliata.*
Rel. 9: *Selaginella selaginoides, Juncus filiformis, Calypogeia neesiana.*
Rel. 10: *Luzula sudetica, Juncus filiformis.*
Rel. 12: *Picea excelsa.*
Rel. 13: *Sphagnum fallax.*
Rel. 14: *Carex rostrata, Calliergon stramineum, Dicranum scoparium* var. *paludosum, Cladopodiella fluitans, Tayloria serrata.*
Rel. 15: *Carex rostrata, Juncus filiformis, Equisetum sylvaticum, Solidago virgaurea* ssp. *alpestris.*
Rel. 18: *Sphagnum fallax.*
Rel. 19: *Eriophorum angustifolium.*
Rel. 20: *Eriophorum angustifolium.*
Rel. 23: *Sphagnum flexuosum.*
Rel. 24: *Calliergon stramineum, Sphagnum fallax.*
Rel. 25: *Arnica montana, Carex rostrata.*
Rel. 26: *Pinus mugo.*
Rel. 27: *Leontodon helveticus, Loiseleuria procumbens, Rhododendron ferrugineum.*
Rel. 28: *Cephalozia pleniceps, Eriophorum angustifolium, Calliergon stramineum.*
Rel. 29: *Carex panicea, Luzula sudetica, Anthoxanthum odoratum, Loiseleuria procumbens.*
Rel. 30: *Leucobryum glaucum, Arnica montana, Loiseleuria procumbens.*
Rel. 31: *Arnica montana, Deschampsia caespitosa, Euphrasia rostkoviana, Eriophorum angustifolium, Willemetia stipitata, Carex rostrata, Festuca rubra, Luzula sudetica, Anthoxanthum odoratum, Solidago virgaurea* ssp. *alpestris.*

Tab. 16 - ***Eriophoro-Trichophoretum cespitosi***

Rel. 1: *Caltha palustris* ssp. *laeta, Cirsium palustre, Valeriana dioica, Cladopodiella fluitans, Tayloria serrata, Cephalozia bicuspidata, Potentilla palustris.*
Rel. 2: *Trichophorum alpinum, Vaccinium uliginosum, Cladopodiella fluitans, Tayloria serrata.*
Rel. 3: *Odontoschisma elongatum, Hypnum pratense, Carex limosa, Pleurozium schreberi.*
Rel. 4: *Juncus alpino-articulatus.*
Rel. 5: *Juncus conglomeratus, Agrostis canina.*
Rel. 6: *Hieracium alpinum.*
Rel. 7: *Vaccinium myrtillus, Vaccinium uliginosum, Campanula scheuchzeri, Sphagnum quinquefarium.*
Rel. 8: *Odontoschisma elongatum, Vaccinium myrtillus, Loiseleuria procumbens, Rhododendron ferrugineum, Cephaloziella elachista, Sphagnum quinquefarium, Hylocomium pyrenaicum, Cetraria islandica.*
Rel. 9: *Carex limosa, Odontoschisma elongatum.*
Rel. 10: *Leucobryum glaucum, Gymnocolea inflata, Pinus mugo, Odontoschisma denudatum.*
Rel. 11: *Equisetum palustre.*
Rel. 12: *Calliergon sarmentosum, Equisetum palustre, Tofieldia calyculata, Hypnum pratense, Gymnocolea inflata, Dactylorhiza fuchsii, Allium schoenoprasum* ssp. *sibiricum, Polytrichum juniperinum.*
Rel. 13: *Calliergon sarmentosum, Dactylorhiza fuchsii, Solidago virgaurea* ssp. *alpestris, Sphagnum girgensohnii, Sphagnum teres, Cephalozia bicuspidata.*
Rel. 14: *Vaccinium myrtillus, Leucobryum glaucum, Juniperus nana, Dicranum* sp.
Rel. 15: *Calliergon sarmentosum, Carex panicea, Carex lepidocarpa, Carex limosa.*
Rel. 17: *Menyanhtes trifoliata, Carex panicea, Carex lepidocarpa, Campylium stellatum, Tofieldia calyculata, Trichophorum alpinum, Polygala* sp. *Cirsium helenioides.*

Rel. 18: *Campylium stellatum, Trichophorum alpinum, Vaccinium uliginosum, Drepanocladus revolvens, Drosera anglica.*
Rel. 19: *Menyanthes trifoliata, Carex davalliana, Carex lepidocarpa, Tofieldia calyculata, Dactylorhiza fuchsii, Trollius europaeus, Ranunculus acris, Sphagnum girgensohnii.*

Tab. 17 - ***Pino mugo-Sphagnetum***

Rel. 2: *Homogyne alpina, Maianthemum bifolium, Rhytidiadelphus triquetrus.*
Rel. 3: *Juniperus nana, Sphagnum flexuosum, Cephalozia pleniceps.*
Rel. 4: *Cephaloziella elachista, Polytrichum commune, Cephalozia bicuspidata.*
Rel. 6: *Carex stellulata, Aulacomnium palustre, Trichophorum caespitosum, Calliergon stramineum.*

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