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Phytosociological and ecological relations in the communities with the share of *Carex chordorrhiza* L. f. inside and outside the dense geographical species range

Fitosocjologiczne i ekologiczne relacje w zbiorowiskach z udziałem *Carex chordorrhiza* L. f. w strefie zwartego geograficznego zasięgu gatunku i poza nim

SUMMARY

The aim of this study was to investigate and evaluate the sociological relations of communities with the share of *C. chordorrhiza* L. f. in the area inside the dense geographical range (IGR), and to compare the data with records from outside the dense geographical range OGR). We also described the environmental conditions with the use of the phytoindication method, and indicated phytocoenotic factors affecting the protection of the population of this threatened species.

String sedge was most frequently noted in the *Sphagno-Caricetum rostratae* association. The OGR communities contain a smaller number of species, and especially of trees, shrubs and herbaceous plants. *Eriophorum vaginatum, Sphagnum capillifolium, Lysimachia vulgaris, Scheuchzeria palustris, Polytrichum strictum*, or *Straminergon stramineum*, i.e., species whose frequency and coverage is high in the IGR communities, were not observed here. The IGR communities are found in relatively poor and highly acidified habitats, whereas the OGR communities occur in various habitats and are more diverse floristically. The present results demonstrate that large threat for *C. chordorrhiza* is posed by tree and shrub expansion (*Betula pubescens, B. pendula* and *Salix cinerea*), which has been reported for many years and is often caused by drainage.

STRESZCZENIE

Celem pracy było przedstawienie fitosocjologicznych relacji w zbiorowiskach roślinnych z udziałem *Carex chordorrhiza* L. f. położonych w granicy zwartego zasięgu tego gatunku (IGR)

oraz w izolowanych stanowiskach poza zwartym zasięgiem (OGR). Przedstawiono ocenę warunków siedliskowych, a także wskazano czynniki wewnątrzfitocenotyczne mające wpływ na zachowanie populacji tego zagrożonego gatunku.

Turzycę strunową najczęściej notowano w zespole *Sphagno-Caricetum rostratae*. Zbiorowiska OGR odznaczają się mniejszą liczbą gatunków, a szczególnie mniejszą liczbą drzew, krzewów oraz gatunków zielnych. Nie stwierdzono tutaj *Eriophorum vaginatum, Sphagnum cappilifolium, Lysimachia vulgaris, Scheuchzeria palustris, Polytrichum strictum, Straminergon stramineum* – gatunków, które w fitocenozach IGR odznaczały się wysoką frekwencją i pokryciem. Zbiorowiska IGR występują w siedliskach stosunkowo ubogich i silnie zakwaszonych, natomiast fitocenozy OGR cechują się większym zróżnicowaniem florystycznym oraz większą różnorodnością siedlisk. Z prezentowanych rezultatów badań wynika, że dość duże zagrożenie dla *C. chordorrhiza* stanowi ekspansja drzew i krzewów (*Betula pubescens, B. pendula, Salix cinerea*), rejestrowana od wielu lat i bardzo często spowodowana osuszeniem.

K e y w o r d s: *Carex chordorrhiza*, boreal plant, species range, phytosociological relations

INTRODUCTION

String sedge *Carex chordorrhiza* L.f. has a circumpolar distribution within the boreal and subarctic regions. This boreal-montane species is widely distributed in Eurasia and North America. It is common in Iceland, Scandinavia, Finland and Russia, but has a sporadic distribution in boreal areas of Europe and in North America (19, 33, 37). It was also reported from single localities in western and southern Europe (14, 41, 49).

C. chordorrhiza is declared rare and endangered (23, 26, 27), which disappeared from many of its former localities as a result of drainage (13, 15, 18, 40). The restricted distribution of *C. chordorrhiza* in many countries gives it threatened species status. In Europe, it is included in the Red Data Books (6, 23, 30).

In Poland *C. chordorrhiza* is regarded as a glacial relic. The species reaches the southwestern border of the dense geographical range (19). It was reported from a number of localities in the north-eastern part of the country (1, 40) and in Western Pomerania, where it inhabits isolated localities (2, 3, 4, 5, 15, 50). In eastern Poland (the Polesie Region) *C. chordorrhiza* was recorded from a range of transitional mire communities (9, 10, 11, 12, 13, 21, 31, 44). In many regions of Poland *C. chordorrhiza* was found only in isolated localities (38, 51).

The main aims of this study were: (i) to investigate and evaluate the sociological relations of communities with the share of *C. chordorrhiza* in the area inside the dense geographical range, and to compare the data with records from outside the dense geographical range; (ii) to evaluate the environmental conditions with the use of the phytoindication method; (iii) to indicate phytocoenotic factors affecting the protection of the populations of this threatened species.

MATERIAL AND METHODS

The study was performed in the last decade inside the dense geographical range of *Carex chordorrhiza* on the mires of lakes: Długie, Czarne Gościnieckie, Miejskie, Moszne (IGR) in the area of the Łęczna-Włodawa Lakeland (mid-eastern Poland), and isolated sites localized outside the dense geographical species range (OGR) – the reserve Rybojady (mid-western Poland), and in Gomunice near Radomsko and Lake Mielno (Central Poland). In the chosen communities with the share of *Carex chordorrhiza*, phytosociological relevés were made using an eleven-degree scale, with + symbol for the species coverage less than 5%, 1 – for cover of 5–10%, 2 – for 10–20%, ..., 10 – for

90–100%. The entire data set was analysed using Detrended Correspondence Analysis (DCA) (17) to examine floristic gradients in the vegetation. In order to characterize the environmental preferences of the species in the relevés, the weighted averages of the indicator values for moisture (F), reaction (R), nitrogen content (N), light (L), temperature (T), and continentality (K) were calculated (8) taking into account the abundance values of the species. In order to analyse the mean environmental gradients, the results of ordination – scores of relevés of the first two DCA axes (with the highest eigenvalues) – were correlated with the corresponding weighted averages of the above-mentioned indicator values.

On the basis of phytosociological relevés, the following parameters were calculated: total number of species (TNS), number of trees and shrubs (NTS), number of herb species (NH), number of bryophytes (NB), and coverage of particular layers: trees (TC), shrubs (SC), herb (HC) and bryophytes (BC). In order to analyse the changes of diversity and structure of communities along the environmental gradients, the results of ordination – scores of relevés of the first two DCA axes – were correlated with the corresponding calculated parameters. The calculated parameters were correlated with the abundance of *Carex chordorrhiza*. The Spearman's rank correlation coefficient was used to show the correlation. The MVSP and Statistica analysis program was used to analyze all the data. The nomenclature follows Mirek et al. (34) for vascular plants and Ochyra et al. (36) for bryophytes.

RESULTS

The DCA results indicate floristic differentiation of the communities with the share of *C. chordorhiza* occurring in the area inside the dense geographical range (IGR) and outside the dense geographical range (OGR) (Fig. 1, 2). The high indicator values of axis I and II on the DCA diagram demonstrate the presence of two main environmental gradients. The phytosociological relevés representing the communities are distributed along both axis I and II. Variables R, N and NH are negatively correlated with the axis, while variable BC displays positive correlation (Tab. 1). This indicates that this axis reflects the gradient of the acidity increase, decreased trophic levels, bryophyte coverage increase, and of a decline in the number of herbaceous species. A very specific phytosociological relevé (4) representing the Lake Mielno mire community is placed on the left of the diagram (Fig. 2). The floristic composition of the community with the share of *C. chordorrhiza* is remarkably different from both the IGR communities and the localities in the vicinity of Gomunice and Rybojady. It is characterized by a relatively high value of the R indicator, which implies neutral reaction of the soil, whereas the values of the indicator in the other localities indicating acidic reaction. Besides, this community is characterized by the smallest number of species. Interestingly, there is a relatively low BC with the share of such species like *Limprichtia cossoni* and *Campylium stellatum*, which are characteristic of fens and have not been reported from the other study communities (Fig. 2). Absence of species from the genus *Sphagnum* and taxa from the *Oxycocco-Sphagnetea* class is a specific trait.

On the right side of the diagram there are phytosociological relevés of the IGR communities and those from Gomunice and Rybojady area. They are highly

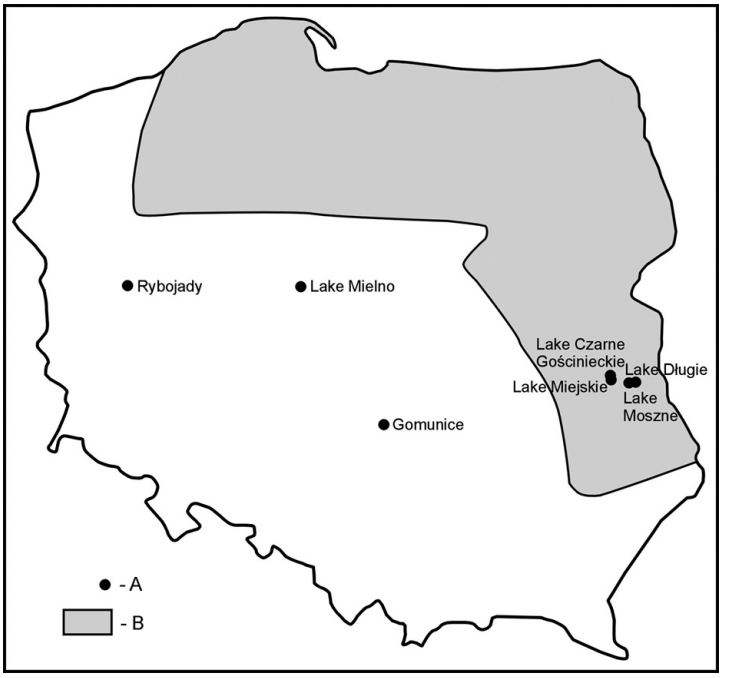

Figure 1. Location of the studied communities with the share of *Carex chordorrhiza*; A – sites of *C. chordorrhiza*, B – the dense geographical species range, according to Hultén and Fries (1986)

dense and cover a small part of the area, which testifies to their marked floristic similarity. However, phytosociological relevés 1, 2 and 3 from the OGR communities are slightly distant from the others in the axis II gradient (Fig. 2).

Table 1. Rank Spearman correlation between DCA axes 1 and 2 and some parameters; *0.01<P≤0.05, **0.001<P≤0.01, ***P≤0.001

	F	R	N	L	T	K	TNS	NTS	NH	NB	TC	SC	HC	BC
Axis 1	-0.06	-0.47*	-0.58**	-0.07	-0.02	0.18	-0.13	-0.13	-0.48*	-0.21	0.10	-0.14	-0.36	0.53*
Axis 2	-0.17	0.40	0.45*	-0.21	0.21	-0.54**	0.56**	0.56**	0.52*	0.34	0.34	0.70***	-0.08	-0.16

Axis II is significantly correlated with parameters N, TNS, NTS and SC (Tab. 1). The highest value of Spearman's correlation coefficient was calculated for the shrub coverage. The mire communities with the share of *C. chordorrhiza* from the area of Gomunice are characterized by absence of a shrub layer – *Betula pubescens, Pinus sylvestris, Alnus glutinosa*, and *Salix cinerea* species. Tree and shrub species were observed here only sporadically in the undergrowth layer. The positive correlation of axis II with the TNS, NTS and NH indicators as well as the inconsiderable distance on this axis between the IGR communities and those from

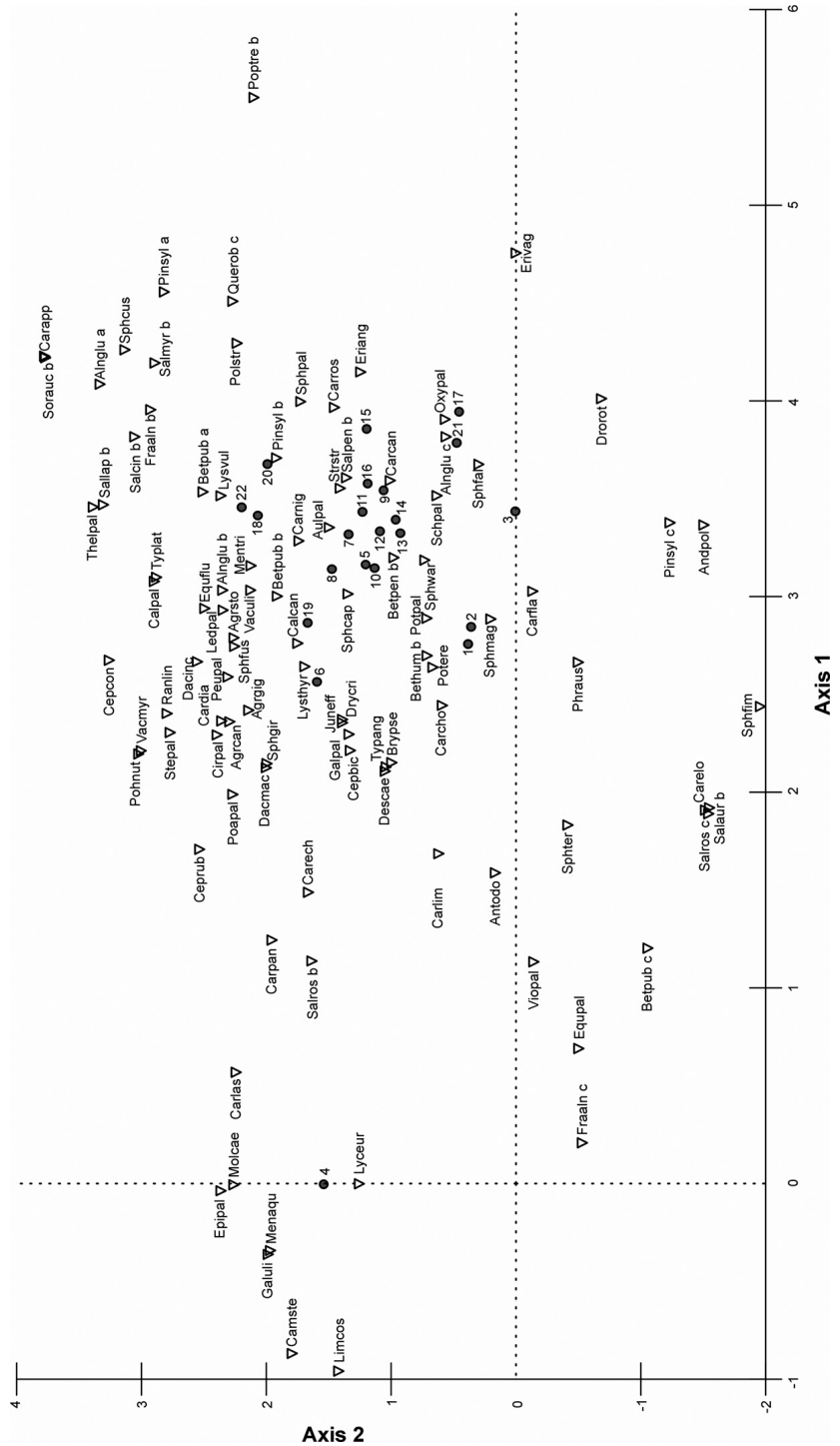

Figure 2. Diagram of ordination of the phytosociological relevés and species on the two first DCA axes; sites: 1–2 – Gomunice, 3 – Rybojady, 4 – Mielno, 5–12 – Długie, 13 – Czarne Gościnieckie, 14–18 – Miejskie, 19–22 – Moszne

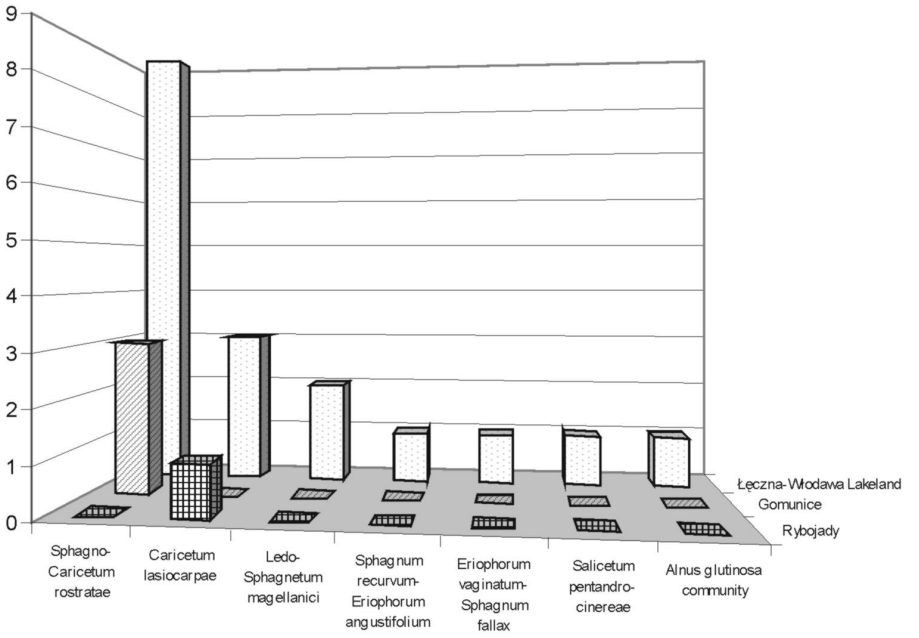

Figure 3. Number of appearances of *Carex chordorrhiza* in the particular communities

Gomunice area prove that the OGR communities contain a smaller number of species, and especially of trees, shrubs and herbaceous plants. *Eriophorum vaginatum, Sphagnum nemoreum, Lysimachia vulgaris, Scheuchzeria palustris, Polytrichum strictum*, or *Straminergon stramineum*, i.e., species whose frequency and coverage is high in the IGR communities, were not observed here. Lower density of bryophyte layer was also reported here. Species that were absent from the IGR communities: *Sphagnum fimbriatum, S. teres*, and *Limprichtia cossoni* were recorded in the OGR communities.

Trees and shrubs influence the String sedge cover. This is confirmed by the negative correlation between the coverage of this species and the number of trees and shrubs, and the density of shrub layer (Tab. 2). The common mire *Betula pubescens, B. pendula, Salix cinerea* and *Pinus sylvestris* are remarkably competitive species.

Table 2. Rank Spearman correlations between cover of *Carex chordorrhiza* and number of species and cover of particular layers in the communities; P≤0.05

NTS	TNS	NH	NB	TC	SC	HC	BC
-0.50	-0.50	-0.08	-0.23	-0.28	-0.52	0.01	-0.11

From the phytosociological point of view, *C. chordorrhiza* was most frequently reported in the *Sphagno-Caricetum rostratae* association (Fig. 3). In the OGR localities, the bryophyte layer was dominated by *Sphagnum fallax*, whereas in

the IGR mires this species was abundantly accompanied by *S. palustre*. A smaller number of appearances was reported from the *Caricetum lasiocarpae* community, but, as it was mentioned above, the IGR communities had a markedly different floristic composition than that of Lake Mielno.

DISCUSSION

In Scandinavia and Finland *Carex chordorrhiza* forms a component of the low sedge vegetation of transitional mires and the sedge dominated "flarks" of raised mires (37). In Poland, *C. chordorrhiza* is characteristic of the relic community *Caricetum chordorrhizae* Paul et Lutz 1941 of a continental-boreal type of range. It is known from few localities in the north-eastern part of the country (32). In the middle-eastern Poland, string sedge was often noted in the transitional mires adjoining many lakes (9, 10, 11, 31, 44, 45), in the associations *Sphagno-Caricetum rostratae* (21) and *Caricetum limosae* (12). The habitat was characterized by low trophism and high acidity. The present study reports similar traits and sociological relations, namely, co-occurrence of *C. chordorrhiza* with such taxa as *Menyanthes trifoliata, Potentilla palustris, Oxycoccus palustris*, which are characteristic of communities with the share of *C. chordorrhiza* and which were recorded many years ago (9, 21, 25). The co-occurrence of these species is closely linked both inside the dense geographical range (IGR) and in isolated localities in Europe; however, the composition of bryophytes may be different (7, 24, 42).

Comparison of the IGR and OGR communities with the share of *C. chordorrhiza* reveals differences in the floristic composition and habitat traits. The IGR communities are found in relatively poor and highly acidified habitats, whereas the OGR ones occur in various habitats and are more diverse floristically. A relatively high floristic and habitat diversity is characteristic of the communities in isolated sites with neutral reaction in the Czech Republic and Slovakia (7, 42, 47). Relatively fertile habitats of this species with the share of, among others, *Drepanocladus revolvens, Scorpidium scorpioides* and *Campyllium stellatum* was reported from Germany (22). In Scotland, there was no share of bryophytes in the *C. chordorrhiza* communities, and the species localities recorded in riverine wetlands displayed pH 5.7–7.3 and high Ca and Mg contents (24).

Development of urban agglomerations was one of the causes of disappearance of the species isolated localities in Western Europe (29). Many localities of the species outside the dense geographical range are threatened (20, 35, 43). The present results demonstrate that large threat for *C. chordorrhiza* is posed by tree and shrub expansion (*Betula pubescens, B. pendula* and *Salix cinerea*), which indicates a succession towards woodland communities, which has been reported for

many years and is often caused by drainage (38, 39, 45, 46). The rate of *C. chordorrhiza* disappearance in northern Poland indicates an urgent need for legal protection of the existing localities of this species (3). In many cases the habitats are protected in the areas of Natura 2000, both in Poland (16) and abroad (48). Besides conservation, active protection is advisable which would include removal of appearing trees and bushes, and preventing invasion of more competitive species (among others, *Phragmites australis*) into habitats which support *C. chordorrhiza* (24, 28, 38, 39).

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LIST OF ABBREVIATIONS

Trees and shrubs

Alnglu a	*Alnus glutinosa* (layer a)
Alnglu b	*Alnus glutinosa* (layer b)
Alnglu c	*Alnus glutinosa* (layer c)
Bethum b	*Betula humilis* (layer b)
Betpub a	*Betula pubescens* (layer a)
Betpub b	*Betula pubescens* (layer b)
Betpub c	*Betula pubescens* (layer c)
Betpen b	*Betula pendula* (layer b)
Fraaln b	*Frangula alnus* (layer b)
Fraaln c	*Frangula alnus* (layer c)
Salaur b	*Salix aurita* (layer b)
Salcin b	*Salix cinerea* (layer b)
Sallap b	*Salix lapponum* (layer b)
Salmyr b	*Salix myrtilloides* (layer b)
Salpen b	*Salix pentandra* (layer b)
Salros b	*Salix rosmarinifolia* (layer b)
Salros c	*Salix rosmarinifolia* (layer c)
Sorauc b	*Sorbus aucuparia* (layer b)
Pinsyl a	*Pinys sylvestris* (layer a)
Pinsyl b	*Pinus sylvestris* (layer b)
Pinsyl c	*Pinus sylvestris* (layer c)
Poptre b	*Populus tremula* (layer b)
Querob c	*Quercus robur* (layer c)

Ch.–Cl. *Phragmitetea*

Carapp	*Carex appropinquata*
Carelo	*Carex elongata*
Carros	*Carex rostrata*
Equflu	*Equisetum fluviatile*
Galpal	*Galium palustre*
Lysthyr	*Lysimachia thyrsiflora*
Peupal	*Peucedanum palustre*
Phraus	*Phragmites australis*
Ranlin	*Ranunculus lingua*
Typang	*Typha angustifolia*
Typlat	*Typha latifolia*

Ch.–Cl. *Scheuchzerio-Caricetea nigrae*

Agrcan	*Agrostis canina*
Carcan	*Carex canescens*
Carcho	*Carex chordorrhiza*
Carech	*Carex echinata*
Cardia	*Carex diandra*
Carfla	*Carex flava*
Carlas	*Carex lasiocarpa*
Carlim	*Carex limosa*
Carnig	*Carex nigra*
Potpal	*Potentilla palustris*
Epipal	*Epipactis palustris*
Eriang	*Eriophorum angustifolium*
Mentri	*Menyanthes trifoliata*
Schpal	*Scheuchzeria palustris*
Stepal	*Stellaria palustris*
Viopal	*Viola palustris*

Ch.–Cl. *Molinio-Arrhenatheretea*

Agrsto	*Agrostis stolonifera*
Cirpal	*Cirsium palustre*
Descae	*Deschampsia caespitosa*
Equpal	*Equisetum palustre*
Galuli	*Galium palustre*
Juneff	*Juncus effusus*
Lysvul	*Lysimachia vulgaris*
Molcae	*Molinia caerulea*
Poapal	*Poa palustris*

Ch.–Cl. *Oxycocco-Sphagnetea*

Andpol	*Andromeda polifolia*
Drorot	*Drosera rotundifolia*
Erivag	*Eriophorum vaginatum*
Oxypal	*Oxycoccus palustris*

Ch.–Cl. Vaccinio-Piceetea

Ledpal	Ledum palustre
Vacmyr	Vaccinium myrtillus
Vaculi	Vaccinium uliginosum

Accompanying species

Agrgig	*Agrostis gigantea*
Antodo	*Anthoxanthum odoratum*
Calcan	*Calamagrostis canescens*
Calpal	*Calla palustris*
Carpan	*Carex panicea*
Ceprub	*Cephalanthera rubra*
Dacinc	*Dactylorhiza incarnata*
Dacmac	*Dactylorhiza maculata*
Drycri	*Dryopteris cristata*

Menaqu	*Mentha aquatica*
Lyceur	*Lycopus europaeus*
Potere	*Potentilla erecta*
Thelpal	*Thelypteris palustris*

Bryophytes

Aulpal	*Aulacomnium palustre*
Brypse	*Bryum pseudotriquetrum*
Camste	*Campylium stellatum*
Cepcon	*Cephalozia connivens*
Cepbic	*Cephalozia bicuspidata*
Limcos	*Limprichtia cossoni*
Pohnut	*Pohlia nutans*
Polstr	*Polytrichum strictum*
Sphcap	*Sphagnum capillifolium*
Sphcus	*Sphagnum cuspidatum*
Sphfal	*Sphagnum fallax*
Sphfim	*Sphagnum fimbriatum*
Sphfus	*Sphagnum fuscum*
Sphgir	*Sphagnum girgensohnii*
Sphmag	*Sph magellanicum*
Sphpal	*Sphagnum palustre*
Sphter	*Sphagnum teres*
Sphwar	*Sphagnum warnstorfii*
Strstr	*Straminergon stramineum*