

Holocene history of West-Carpathian calcareous fen vegetation

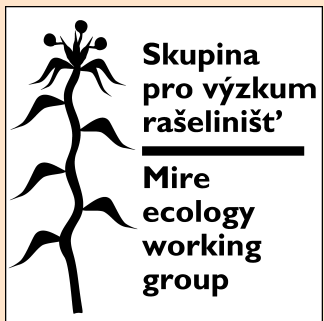
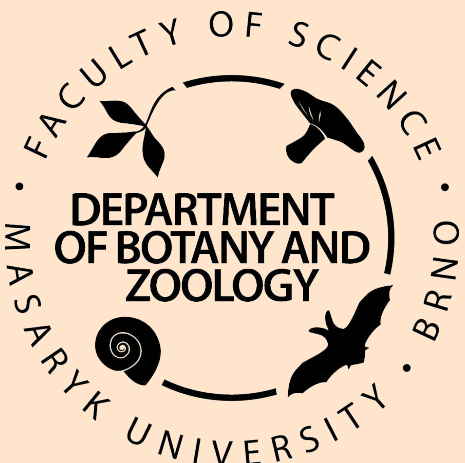
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Question and Study area

How long is the history of calcareous fens in the West Carpathians? Are there differences between Outer Carpathians and Inner Carpathians, where many species considered as glacial relicts occur? We explored 45 well-preserved calcareous tufa-forming and extremely rich peat-forming fens (*Caricion davallianae* alliance) in both parts of the West Carpathians.



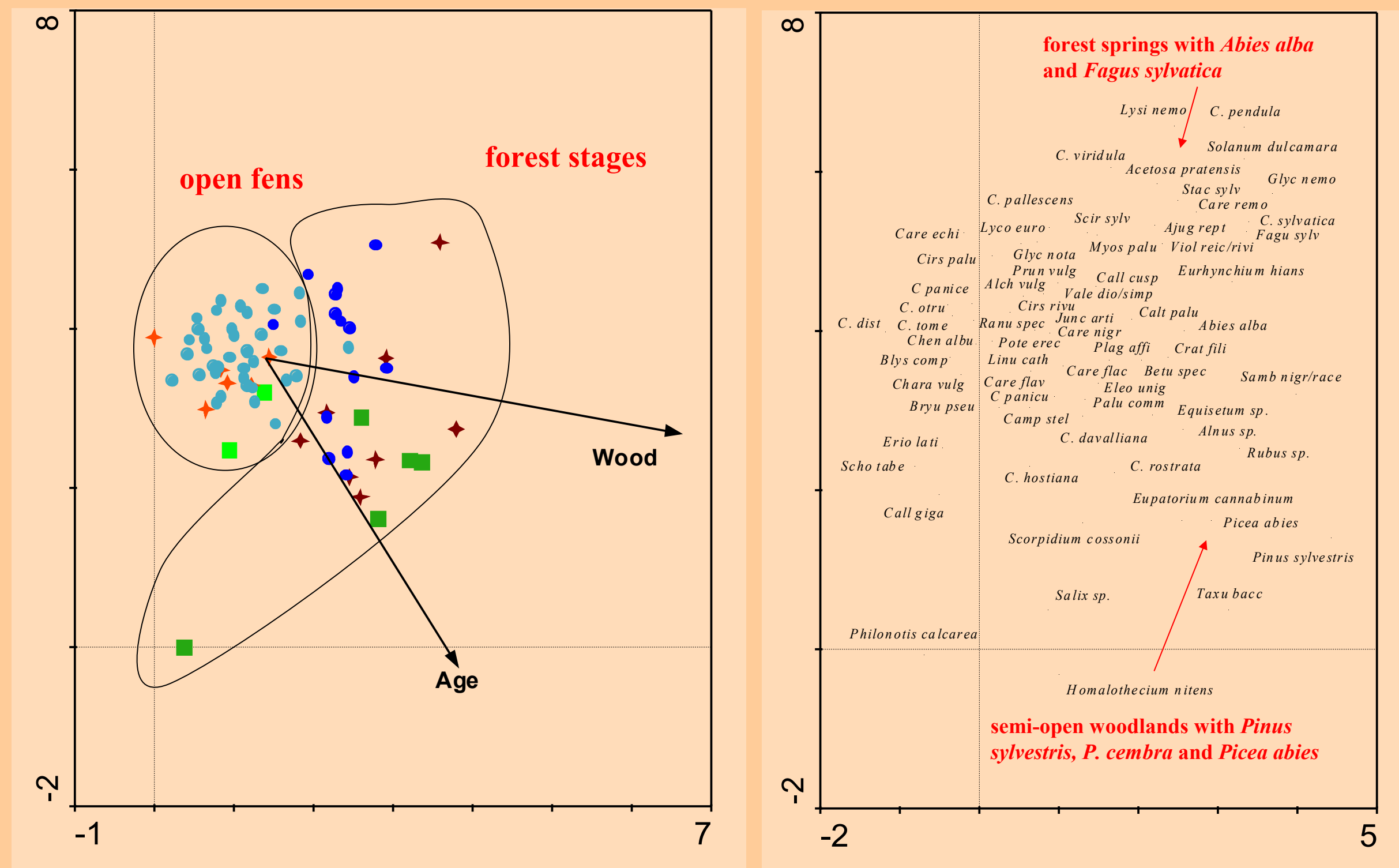
Materials and Methods

In the deepest part of each fen, we took the samples from the bottom of the sediment and, if wooded developmental stage was present at the bottom, from the transition between forested and open fen indicated in the field by a disappearance of wood and an appearance of light-demanding mollusc species (*Vallonia* spp.). All sediment samples (n= 75) were dated by C14. We present uncalibrated C14 data. We analysed plant macrofossils (presented here), molluscs and pollen. Standard macrofossil analysis (according to Berglund et al. 1986) was carried out. Preserved macrofossils were determined using Beijerinck (1976) and Bojňanský et Fargašová (2007) for seeds, Schweingruber (1982) for wood, Smith (1996) for bryophytes and recent seed collection of Botanical Institute AV ČR (<http://www.ibot.cas.cz>).

Detrended Correspondent Analysis (DCA) with down-weighted rare species was used to show the relationships between the species composition of the samples and measured variables (age, wood content). Data in presence/absence format were analysed using the CANOCO 4.5 package (ter Braak and Šmilauer, 2002).

Results

DCA diagram demonstrates the differences in species composition of analysed samples along the first and second ordination axis. Samples with open-fen species are placed in the left part of the diagram, whereas samples with trees and shady-demanding species are placed in the right part. Samples from forest stages are more diversified then the samples from open stands along the second ordination axis, which correlates partially with the dated age of the sample.



Explanations:

Circles: young fens (less than 3000 uncal yrs BP), stars: intermediate-old fens (3000-8000 uncal yrs BP), squares: old fens (8000-13000 uncal yrs BP). List of abbreviated names: *Acetosa pratensis*, *Ajuga reptans*, *Alchemilla vulgaris* agg., *Betula* species, *Blysmus compressus*, *Bryum pseudotriquetrum*, *Calliergon giganteum*, *Calliergonella cuspidata*, *Caltha palustris*, *Campyllum stellatum*, *Carex distans*, *C. echinata*, *C. flacca*, *C. flava/lepidocarpa*, *C. nigra*, *C. otrubae*, *C. panicea*, *C. paniculata*, *C. remota*, *C. tomentosa*, *Chara vulgaris*, *Chenopodium album* agg., *Cirsium rivulare*, *C. palustre*, *Cratoneuron filicinum*, *Eleocharis uniglumis*, *Eriophorum latifolium*, *Fagus sylvatica*, *Glyceria nemoralis*, *G. notata*, *Juncus articulatus*, *Lycopodium europaeus*, *Lysimachia nemorum*, *Myosotis palustris* agg., *Palustriella commutata*, *Plagiommium affine* agg., *Potentilla erecta*, *Prunella vulgaris*, *Ranunculus species*, *Sambucus nigra/racemosa*, *Schoenoplectus tabernaemontani*, *Scirpus sylvaticus*, *Stachys sylvatica*, *Valeriana dioica/simplicifolia*, *Viola reichenbachiana/riviniana*.

We confirmed that the Inner-Carpathian fens have older history, especially longer continuity of open, treeless calcareous fens. Further, Late-Glacial and Early-Holocene forested phases are with coniferous trees in the Inner Carpathians allowing more light to penetrate through the canopy.

	Outer West Carpathians	Inner West Carpathians
the oldest forest stage	7950 uncal yrs BP	13 810 uncal yrs BP
the oldest open fen	2220 uncal yrs BP	12170 uncal yrs BP

Percentage synoptic table of the six developmental stages (old, intermediate-old and young open fen and forest stage). Macrofossil types are given in brackets (s: seed, st: stems, lvs: leaves, w: wood, rh: rhizomes, n: needles, oog: oogonia).

Group No.	1	2	3	4	5	6
No. of samples	2	5	7	7	38	14
old open fens (8000-13000 BP)						
<i>Potamogeton pusillus</i> agg. (s)	50	.	.	.	.	.
<i>Ditrichum crispatisimum</i> (st, lvs)	50	.	.	.	.	.
old forest stage						
<i>Sphagnum teres</i> (lvs)	.	40	.	.	.	.
<i>Sphagnum palustre</i> (lvs)	.	20	.	.	.	.
<i>Philonotis calcarea</i> (st, lvs)	.	20	.	.	8	.
<i>Eupatorium cannabinum</i> (s)	.	20	.	.	8	.
<i>Pinus cembra</i> (w)	.	20	.	.	.	.
<i>Carex lasiocarpa</i> (s)	.	20	.	.	.	.
<i>Pinus sylvestris</i> (w, n)	.	60	14	.	.	.
intermediate-old open fens (8000-3000 BP)						
<i>Lycopodium europaeus</i> (s)	.	.	29	.	8	.
<i>Lotus corniculatus</i> (s)	.	.	14	.	.	.
<i>Trichophorum pumilum</i> (s)	.	.	14	.	3	.
<i>Lychnis flos-cuculi</i> (s)	.	.	14	.	3	.
<i>Calliergon giganteum</i> (st, lvs)	.	.	14	.	5	.
<i>Carex hostiana</i> (s)	.	.	14	.	5	.
<i>Triglochin maritimum</i> (s)	.	.	14	.	.	.
<i>Campyllum polygamum</i> (st, lvs)	.	.	14	.	.	.
intermediate-old forest stage						
<i>Atropa bella-donna</i> (s)	.	.	.	14	.	7
<i>Solanum dulcamara</i> (s)	.	.	.	14	5	.
<i>Cardamine amara</i> (s)	.	.	.	14	.	7
young open fens (less than 3000 BP)						
<i>Linum catharticum</i> (s)	.	.	.	.	39	.
<i>Alchemilla vulgaris</i> agg. (fr, s)	.	.	.	.	18	7
<i>Cirsium palustre</i> (s)	.	.	.	.	16	7
<i>Carex tomentosa</i> (s)	.	.	.	.	16	.
<i>Cirsium rivulare</i> (s)	.	.	.	.	13	.
<i>Carex pallescens</i> (s)	.	.	.	.	11	7
<i>Carex echinata</i> (s)	.	.	.	.	11	.
<i>Carex otrubae</i> (s)	.	.	.	.	11	.
young forest stage						
<i>Carex pendula</i> (s)	.	.	.	.	5	21
<i>Acetosa pratensis</i> (s)	.	.	.	.	3	21
<i>Stachys sylvatica</i> (s)	.	.	.	.	5	21
<i>Thuidium philibertii</i> (st, lvs)	.	.	.	.	.	14
<i>Viola reichenbachiana/riviniana</i> (s)	.	.	.	.	5	14
other species with high frequency						
<i>Carex flava/lepidocarpa</i> (s)	100	.	71	.	87	43
<i>Carex flacca</i> (s)	.	.	29	14	63	7
<i>Potentilla erecta</i> (s)	.	.	71	.	63	14
<i>Carex panicea</i> (s)	.	.	14	.	50	7
<i>Carex nigra</i> (s)	50	.	14	.	50	21
<i>Carex paniculata</i> (s)	.	.	14	.	50	7
<i>Equisetum species</i> (rh, st)	.	40	14	57	42	36
<i>Campyllum stellatum</i> (st, lvs)	50	.	14	.	39	.
<i>Calliergonella cuspidata</i> (st, lvs)	.	.	14	.	39	14
<i>Blysmus compressus</i> (s)	50	.	29	.	34	7
<i>Carex distans</i> (s)	.	.	14	.	32	.
<i>Scorpidium cossonii</i> (st, lvs)	50	.	57	29	32	21
<i>Juncus articulatus</i> (s)	.	.	29	.	29	7
<i>Prunella vulgaris</i> (s)	.	.	14	.	29	14
<i>Ajuga reptans</i> (s)	.	.	.	.	29	43
<i>Rubus species</i> (s)	.	20	14	43	26	64
<i>Carex remota</i> (s)	.	.	.	14	24	43
<i>Carex davalliana</i> (s)	.	20	29	.	18	.
<i>Chara vulgaris</i> (oog)	50	.	.	.	18	.
<i>Caltha palustris</i> (s)	.	.	14	.	18	7
<i>Carex rostrata</i> (s)	100	.	.	.	18	14
<i>Bryum pseudotriquetrum</i> (st, lvs)	100	.	57	.	16	7
<i>Cratoneuron filicinum</i> (st, lvs)	50	.	.	.	13	21
<i>Salix species</i> (w)	50	20	.	14	13	14
<i>Eurhynchium hians</i> (st, lvs)	.	.	14	14	11	36
<i>Glyceria nemoralis</i> (s)	.	.	.	14	11	29
<i>Scirpus sylvaticus</i> (s)	.	.	14	.	11	21
<i>Carex sylvatica</i> (s)	.	.	.	14	8	29
<i>Eleocharis uniglumis</i> (s)	.	.	14	.	5	14
<i>Homalothecium nitens</i> (st, lvs)	50	20	.	14	3	.
<i>Schoenoplectus tabernaemontani</i> (s)	.	.	14	14	3	.
<i>Sambucus nigra/racemosa</i> (s)	.	40	14	29	11	43
<i>Ranunculus species</i> (s)	50	.	57	14	50	29
<i>Valeriana dioica/simplicifolia</i> (s)	50	.	14	.	24	7
<i>Plagiommium affine</i> agg. (st, lvs)	50	.	14	.	11	7
<i>Palustriella commutata</i> (st, lvs)	100	.	29	.	63	43
other tree species						
<i>Picea abies</i> (w, n, s)	50	60	29	29	26	36
<i>Betula species</i> (w, s)	50	20	.	.	18	7
<i>Alnus species</i> (w, s)	50	.	14	43	24	50
<i>Abies alba</i> (w, n, s)	.	.	14	29	26	43
<i>Taxus baccata</i> (w)	.	.	.	29	8	14
<i>Fagus sylvatica</i> (w, s)	.	.	.	14	8	36

Conclusions

- The most of fens were dated as young (< 3 000 uncal yrs BP; 26 sites). Intermediate-old fens (3 000- 8000 uncal yrs BP) were less frequent (13 sites) and old fens (8 000-13 000 uncal yrs BP) were rare (6 sites).
- We revealed continual existence of treeless calcareous fen vegetation from the Late Glacial on some localities (10 500 uncal yrs BP, Hozelec; 12 170 uncal yrs BP Valalská voda).
- Old semi-open fen woodlands occurred only in the Inner West Carpathians. Tree layer was formed by *Pinus cembra*, *P. sylvatica* and *Picea abiea*, which have co-occurred with open-fen bryophytes and vascular plants.
- Young forest-spring phases occurred in both, the Inner and Outer West Carpathians. They were composed of the species such as *Carex pendula*, *C. remota*, *C. sylvatica*, *Glyceria nemoralis* or *Stachys sylvatica* and trees *Abies alba*, *Alnus* sp. and *Fagus sylvatica*.
- We confirmed the occurrence of *Pinus cembra* in fens of the Liptov Basin in the Late Glacial/Early Holocene.
- Taxus baccata* was surprisingly frequent in calcareous fens in the Inner Carpathians (6400-470 uncal yrs BP).

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The 1st documented occurrence of fen species (uncal yrs BP)

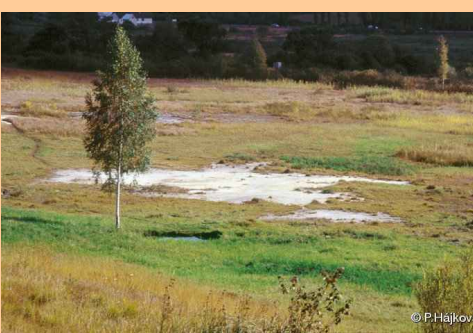
<i>Carex lasiocarpa</i>	13 810
<i>Sphagnum teres</i>	13 810
<i>Carex davalliana</i>	13 810
<i>Homalothecium nitens</i>	12 170
<i>Palustriella commutata</i>	12 170
<i>Carex nigra</i>	12 170
<i>Blysmus compressus</i>	12 170
<i>Carex flava/lepidocarpa</i>	12 170
<i>Carex rostrata</i>	12 170
<i>Bryum pseudotriquetrum</i>	12 170
<i>Valeriana dioica/simplicifolia</i>	12 170
<i>Potamogeton pusillus</i> agg.	10 540
<i>Ditrichum crispatisimum</i>	10 540
<i>Chara vulgaris</i>	10 540
<i>Scorpidium cossonii</i>	10 540
<i>Campyllum stellatum</i>	10 540
<i>Eupatorium cannabinum</i>	10 280
<i>Philonotis calcarea</i>	9 640
<i>Sphagnum palustre</i>	9 290
<i>Calliergon giganteum</i>	7 300
<i>Eleocharis uniglumis</i>	7 300
<i>Campyllum polygamum</i>	6 780
<i>Carex panicea</i>	4 345
<i>Carex flacca</i>	4 345
<i>Juncus articulatus</i>	4 345
<i>Schoenoplectus tabernaemontani</i>	3 410
<i>Triglochin maritimum</i>	3 280
<i>Calliergonella cuspidata</i>	3 280
<i>Carex hostiana</i>	3 250
<i>Carex paniculata</i>	3 250
<i>Philonotis marchica</i>	2 620
<i>Carex distans</i>	2 555
<i>Eleocharis quinqueflora</i>	2 220
<i>Carex viridula</i>	2 220
<i>Trichophorum pumilum</i>	1 540
<i>Molinia caerulea</i> s.s.	1 090
<i>Eleocharis palustris</i>	950
<i>Linum catharticum</i>	950
<i>Pedicularis palustris</i>	840
<i>Carex otrubae</i>	840
<i>Molinia arundinacea</i>	570
<i>Eriophorum angustifolium</i>	540
<i>Fissidens adianthoides</i>	510
<i>Eriophorum latifolium</i>	470
<i>Juncus inflexus</i>	380
<i>Carex echinata</i>	320

Examples of the localities with the long fen history

Hozelec (age 10 540 uncal yrs BP), treeless fen from the beginning. Development started from tufa-forming fen with pools occupied by *Chara vulgaris* and *Potamogeton pusillus*.



Belianske lúky (age 9 500 uncal yrs BP), semi-open woodland with *Pinus sylvestris*, *Sphagnum palustre* and open-fen protists. Had changed to bog woodland, after fire to horsetail wetland and later to open calcareous fen.



Stankovany (age 10 280 uncal yrs BP), fen woodland with *Picea abies*, later salt-rich swamp with reed and alder, from 1540 BP open calcareous fen.

