

Ecography

E7534

le Roux, P. C., Virtanen, R., Heikkinen, R. K. and Luoto, M. 2012. Biotic interactions affect the elevational ranges of high-latitude plant species. – *Ecography* 35: xxx–xxx.

Supplementary material

Appendix 1

Specification of GAM models

Generalized additive models were analysed assuming a quasibinomial distribution of errors (implemented after initial analyses revealed strong underdispersion in the majority of models) and applying a logit link function, using the R statistical package (R Development Core Team 2010). This technique was chosen due to its semi-parametric nature (i.e. lacking assumptions about the linearity or symmetry in species-environment relationships, Yee and Mitchell 1991). We implemented Wood's (2011) *gam* function from the *mgcv* package (see also Wood 2006) that estimates the appropriate degrees of smoothness for each model term during model fitting. The degrees of smoothness for each univariate term were initially set at four, and the initial maximum smoothness of the interaction terms was nine (the minimum smoothness allowing for non-linear relationships when interactions are modeled as anisotropic tensor product smooths). The *gam* function's algorithm then tested the extent to which these initial degrees of smoothness could be reduced for each variable without a significant loss of model fit, dropping terms that did not significantly improve the overall model fit (i.e. defining the best-fit model).

References

- R Development Core Team 2011. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing.
- Wood, S. N. 2006. Generalized Additive Models: An Introduction with R. — Chapman & Hall/CRC.
- Wood, S. N. 2011. Fast stable restricted maximum likelihood and marginal likelihood estimation of semiparametric generalized linear models. — Journal of the Royal Statistical Society (B) 73: 3 - 36.
- Yee, T. W. and Mitchell, N. D. 1991. Generalized additive models in plant ecology. — J Veg Sci 2: 587-602.

Table A1. The number of occurrences, cover, altitudinal range and biogeographic distribution of the 24 dominant species. These species were considered abundant, widespread and locally common enough to potentially affect the altitudinal distribution of subordinate species. Abbrev. = species abbreviations used in Tables A2, A3 and A4. Species denoted here 'arctic-alpine' have their main distribution in arctic or alpine areas in continental western Eurasia, species denoted 'boreal' have wider distributions and may occur commonly in arctic-alpine environments.

Species	Abbrev.	Occurrences ¹	Mean cover across all plots (%)	Mean cover where present (%)	Altitudinal range (m)	Biogeographic distribution
Dominant vascular species						
<i>Betula nana</i>	Bet nan	327	4.7	15.4	514	boreal
<i>Carex bigelowii</i>	Car big	172	0.5	3.2	517	arctic-alpine
<i>Cassiope tetragona</i>	Cas tet	205	1.1	5.6	551	arctic-alpine
<i>Deschampsia flexuosa</i>	Des fle	349	2.0	6.1	456	boreal
<i>Empetrum nigrum</i> ssp. <i>hermaphroditum</i>	Emp her	671	14.2	22.9	562	boreal
<i>Festuca ovina</i>	Fes ovi	292	0.5	1.9	562	boreal
<i>Juniperus communis</i>	Jun ico	139	2.1	16.0	401	boreal
<i>Linnaea borealis</i>	Lin bor	321	0.7	2.3	456	boreal
<i>Phyllodoce caerulea</i>	Phy cae	168	0.8	5.2	483	arctic-alpine
<i>Salix herbacea</i>	Sal her	178	0.6	3.9	762	arctic-alpine

<i>Vaccinium myrtillus</i>	Vac myr	362	4.7	14.2	511	boreal
<i>Vaccinium uliginosum</i>	Vac uli	312	2.6	8.9	562	boreal
<i>Vaccinium vitis-idaea</i>	Vac vit	716	4.1	6.1	581	boreal

Dominant bryophyte species

<i>Barbilophozia</i> <i>lycopodioides</i>	Bar lyc	311	0.9	3.1	403	boreal
<i>Dicranum fuscescens</i>	Dic fus	556	2.0	3.9	652	boreal
<i>Gymnomitrium</i> <i>corallioides</i>	Gym cor	111	0.7	6.4	472	arctic-alpine
<i>Hylocomium splendens</i>	Hyl spl	297	2.7	9.8	546	boreal
<i>Pleurozium schreberi</i>	Ple sch	336	3.1	9.9	535	boreal

Dominant lichen species

<i>Cladonia mitis</i>	Cla mit	549	1.0	2.0	628	boreal
<i>Cladonia rangiferina</i>	Cla ran	458	0.6	1.5	628	boreal
<i>Cladonia uncialis</i>	Cla unc	349	0.6	1.9	581	boreal
<i>Flavocetraria nivalis</i>	Fla niv	255	0.6	2.5	634	arctic-alpine
<i>Ochrolechia frigida</i>	Och fri	232	0.9	4.3	608	boreal
<i>Stereocaulon spp.</i>	Ste spp	283	0.6	2.4	899	boreal

¹ In 1080 1 m² plots

Table A2. The impact of dominant species on the upper and lower altitudinal limits of the 156 subordinate species. For subordinate species predicted to occur under both low and high cover of dominant species (i.e. "present species") data are provided for the subordinate species lower (before the slash) and upper elevational limits (after the slash), with "+" indicating expansion, "-" indicating contraction, and "0" indicating no change. Subordinate species predicted to be present under low cover of a dominant species, but absent under high cover of that same species are marked as "lost", which species showing the inverse pattern are listed as "gained". Species marked "absent" show low probability of occurrence irrespective of dominant species cover. Empty cells indicate that a species pair either had inadequate sample size or that the subordinate species altitudinal range was not nested within that of the dominant species. The number of occurrences, altitudinal range and biogeographic distribution of the subordinate species are also provided. Species denoted 'arctic-alpine' have their main distribution in the arctic or alpine areas of continental western Eurasia, species denoted 'boreal' have wider distributions and may occur commonly in arctic-alpine environments. Abbreviations of dominant species names follow Table A1.

Table A2. (continued)

Species	Occurrences	Altitudinal range (m)	Biogeographic distribution	Dominant vascular plant species								
				Betnan	Carbig	Castet	Desfle	Empher	Fesovi	Junico	Linbor	Phycae
<i>Epilobium angustifolium</i>	26	210	boreal					lost	0 / 0	0 / -	lost	
<i>Equisetum pratense</i>	35	240	boreal					lost	0 / 0	0 / 0	0 / -	lost
<i>Equisetum scirpoides</i>	28	389	arctic-alpine	- / +			0 / -		0 / -			
<i>Festuca ovina</i>	292	562	boreal									
<i>Festuca vivipara</i>	46	386	arctic-alpine		- / -	lost		lost	lost			
<i>Geranium sylvaticum</i>	68	211	boreal	lost				lost	0 / -	lost	absent	lost
<i>Gnaphalium supinum</i>	41	410	arctic-alpine		lost			lost	0 / -			
<i>Hierochloë alpina</i>	23	453	boreal									
<i>Hieracium spp.</i>	122	481	boreal	lost				lost	lost			lost
<i>Huperzia selago ssp. arctica</i>	111	577	boreal									
<i>Juniperus communis</i>	139	401	boreal	absent			absent	lost	absent		absent	absent
<i>Juncus triglumis</i>	128	497	arctic-alpine					+ / -	- / -			
<i>Linnaea borealis</i>	321	456	boreal					lost	absent			
<i>Loiseleuria procumbens</i>	30	427	arctic-alpine	lost								
<i>Luzula confusa</i>	104	585	arctic-alpine									
<i>Luzula pilosa</i>	30	162	boreal							lost		
<i>Luzula spicata</i>	33	358	arctic-alpine		absent			lost	lost			
<i>Luzula sudetica</i>	23	350	boreal									- / +
<i>Lycopodium annotinum</i>	92	468	boreal	absent					absent			
<i>Melampyrum pratense</i>	61	146	boreal						0 / +		lost	
<i>Melampyrum sylvaticum</i>	30	147	boreal						+ / +	lost	- / +	
<i>Oxyria digyna</i>	34	295	arctic-alpine		lost	- / -						
<i>Pedicularis lapponica</i>	141	481	boreal	lost				lost	lost			
<i>Phyllodoce caerulea</i>	168	483	arctic-alpine	lost				lost	lost			
<i>Poa alpina</i>	25	428	arctic-alpine		lost				0 / -			
<i>Potentilla crantzii</i>	24	318	boreal		0 / +							
<i>Pyrola minor</i>	29	481	boreal						0 / +			absent

Table A2. (continued)

Species	Occurrences	Altitudinal range (m)	Biogeographic distribution	Dominant vascular plant species								
				Betnan	Carbig	Castet	Desfle	Empher	Fesovi	Junico	Linbor	Phycae
<i>Salix glauca</i>	63	403	boreal	lost			absent		lost		lost	absent
<i>Salix hastata</i>	37	390	boreal	absent					lost			absent
<i>Salix herbacea</i>	178	762	arctic-alpine									
<i>Salix polaris</i>	105	695	arctic-alpine									
<i>Saussurea alpina</i>	82	483	arctic-alpine					lost	lost			
<i>Selaginella selaginoides</i>	48	403	boreal	lost				lost	lost			lost
<i>Sibbaldia procumbens</i>	33	410	arctic-alpine									
<i>Silene acaulis</i>	34	363	arctic-alpine		lost	- / 0		lost	lost			
<i>Solidago virgaurea</i>	230	401	boreal	lost			lost	lost	lost		absent	
<i>Taraxacum spp.</i>	35	377	boreal		lost				lost			lost
<i>Thalictrum alpinum</i>	49	376	arctic-alpine	- / +	lost			- / -	- / -			0 / -
<i>Trientalis europaea</i>	145	376	boreal				lost	lost	lost		lost	
<i>Trisetum spicatum</i>	32	433	arctic-alpine		lost				lost			
<i>Trollius europaeus</i>	53	296	boreal	lost				lost	lost	lost	lost	lost
<i>Vaccinium myrtillus</i>	362	511	boreal					lost	absent			
<i>Vaccinium uliginosum</i>	312	562	boreal									
<i>Vaccinium vitis-idaea</i>	716	581	boreal									
<i>Viola biflora</i>	113	431	arctic-alpine	lost				lost	lost			lost
Subordinate bryophyte species												
<i>Anastrophyllum minutum</i>	132	569	boreal									
<i>Andreaea rupestris</i>	157	527	boreal									
<i>Anthelia juratzkana</i>	111	792	arctic-alpine									
<i>Aulacomnium turgidum</i>	20	398	arctic-alpine									
<i>Barbilophozia attenuata</i>	33	420	boreal	0 / +			lost					
<i>Barbilophozia sp.</i>	40	253	boreal	0 / +			lost				lost	
<i>Barbilophozia hatcheri</i>	87	527	boreal					lost	lost			
<i>Barbilophozia lycopodioides</i>	311	403	boreal				lost	lost	lost		lost	

Table A2. (continued)

Species	Occurrences	Altitudinal range (m)	Biogeographic distribution	Dominant vascular plant species									
				Betnan	Carbig	Castet	Desfle	Empher	Fesovi	Junico	Linbor	Phycae	
<i>Blepharostoma trichophyllum</i>	27	300	boreal		lost	lost							+ / -
<i>Bryum spp.</i>	47	521	boreal										
<i>Conostomum tetragonum</i>	49	692	arctic-alpine										
<i>Dicranum elongatum</i>	41	635	arctic-alpine										
<i>Dicranum fuscescens</i>	556	652	boreal										
<i>Dicranum scoparium</i>	251	567	boreal										
<i>Dicranum spadiceum</i>	53	387	arctic-alpine				- / 0						
<i>Diplophyllum taxifolium</i>	61	763	boreal										
<i>Gymnomitrium concinnatum</i>	165	628	arctic-alpine										
<i>Gymnomitrium corallioides</i>	111	472	arctic-alpine		- / 0								
<i>Hepaticae spp.</i>	141	529	boreal					lost	absent				
<i>Hylocomium splendens</i>	297	546	boreal					lost	absent				
<i>Lophozia sudetica</i>	85	533	boreal										
<i>Pleurocladula albescens</i>	29	465	arctic-alpine		lost								
<i>Pleurozium schreberi</i>	336	535	boreal					lost	absent				
<i>Pogonatum dentatum</i>	88	796	arctic-alpine										
<i>Pogonatum urnigerum</i>	25	263	boreal					absent					
<i>Pohlia cruda</i>	33	434	boreal					lost	- / -				
<i>Pohlia spp.</i>	63	685	boreal										
<i>Pohlia nutans</i>	140	858	boreal										
<i>Polytrichastrum alpinum</i>	101	747	arctic-alpine										
<i>Polytrichum commune</i>	206	403	boreal				lost	lost	absent		lost		
<i>Polytrichum hyperboreum</i>	147	869	arctic-alpine										
<i>Polytrichum juniperinum</i>	229	534	boreal					lost	absent				
<i>Polytrichum piliferum</i>	108	773	boreal										
<i>Polytrichum sexangulare</i>	26	576	arctic-alpine										
<i>Polytrichum strictum</i>	38	421	boreal				lost		absent		absent		

Table A2. (continued)

Species	Occurrences	Altitudinal range (m)	Biogeographic distribution	Dominant vascular plant species									
				Betnan	Carbig	Castet	Desfle	Empher	Fesovi	Junico	Linbor	Phycae	
<i>Ptilidium ciliare</i>	285	562	boreal										
<i>Racomitrium lanuginosum</i>	139	756	boreal										
<i>Sanionia uncinata</i>	103	575	boreal										
<i>Sciuro-hypnum reflexum</i>	76	339	boreal				lost	lost	absent			absent	
<i>Tetralophozia setiformis</i>	103	562	boreal										
<i>Tritomaria quinquedentata</i>	54	754	boreal										
Subordinate lichen species													
<i>Alectoria ochroleuca</i>	107	599	arctic-alpine										
<i>Bryocaulon divergens</i>	87	551	arctic-alpine										
<i>Cetraria crispiformis</i>	262	519	boreal										
<i>Cetrariella delisei</i>	61	656	boreal										
<i>Cetraria ericetorum</i>	137	579	boreal										
<i>Cetraria islandica</i>	115	819	boreal										
<i>Cetraria nigricans</i>	42	441	arctic-alpine										
<i>Cladonia bellidiflora</i>	87	531	boreal										
<i>Cladonia borealis</i>	127	645	boreal										
<i>Cladonia chlorophaea</i>	112	652	boreal										
<i>Cladonia cornuta</i>	65	486	boreal								absent		
<i>Cladonia crispata</i>	85	576	boreal										
<i>Cladonia deformis</i>	94	534	boreal						lost	absent			
<i>Cladonia digitata</i>	122	558	boreal						absent	absent			
<i>Cladonia ecmocyna</i>	52	550	boreal										
<i>Cladonia gracilis</i>	521	628	boreal										
<i>Cladonia maxima</i>	46	376	boreal								lost		lost
<i>Cladonia merochlorophaea</i>	119	521	boreal						lost	- / 0			
<i>Cladonia mitis</i>	549	628	boreal										
<i>Cladonia pleurota</i>	207	551	boreal						lost	absent			

Table A2. (continued)

Species	Dominant vascular plant species				Dominant bryophyte species					Dominant lichen species					
	Salher	Vacmyr	Vaculi	Vacvit	Barlyc	Dicfus	Gymcor	Hylspl	Plesch	Clamit	Claran	Claunc	Flaniv	Ochfri	Stespp
Subordinate vascular plant species															
<i>Alchemilla</i> spp.					0 / 0				- / 0						
<i>Antennaria alpina</i>	- / 0			- / 0		0 / 0				- / 0	lost	lost	lost	- / -	- / 0
<i>Antennaria dioica</i>		0 / -	0 / -		lost	0 / +		- / +		0 / -					
<i>Anthoxanthum odoratum</i> ssp. <i>alpinum</i>		- / 0	lost	lost		lost		lost	lost	gained	absent	- / +			gained
<i>Arctostaphylos alpina</i>											lost				lost
<i>Astragalus alpinus</i>			0 / -	lost		0 / -		- / +	- / +	lost	0 / -				
<i>Bartsia alpina</i>						lost		- / -		lost					
<i>Betula pubescens</i> ssp. <i>czerepanovii</i>		lost	lost		lost	0 / -		absent	lost	lost	lost	lost			lost
<i>Betula nana</i>			lost	lost		lost		lost	lost	lost	lost	lost			lost
<i>Bistorta vivipara</i>	lost		lost	- / +		lost		- / +		lost	gained	lost	lost	lost	- / +
<i>Calamagrostis lapponica</i>			lost	- / +		lost				lost	lost	lost			absent
<i>Campanula rotundifolia</i>		lost	0 / -			lost		0 / -		0 / +	lost				- / +
<i>Carex bigelowii</i>	lost					- / 0				- / 0	lost		lost	lost	0 / +
<i>Carex lachenalii</i>	0 / -					lost				lost		- / -		- / +	
<i>Carex vaginata</i>			0 / -	lost		lost		lost	- / +	lost	lost	lost			lost
<i>Cassiope hypnoides</i>	lost					lost				0 / +	lost		lost	lost	- / +
<i>Cassiope tetragona</i>	lost												lost	lost	lost
<i>Cornus suecica</i>			0 / 0		0 / 0	0 / 0		0 / 0	0 / 0	0 / 0	0 / 0				
<i>Deschampsia flexuosa</i>		lost	lost	lost		lost		lost	lost	absent	lost	absent			absent
<i>Diapensia lapponica</i>			+ / +			- / -					+ / 0	lost	lost	lost	+ / +
<i>Diphasiastrum alpinum</i>	lost	+ / 0												- / 0	- / 0
<i>Dryas octopetala</i>						absent				absent	absent		absent	absent	
<i>Empetrum nigrum</i> spp. <i>hermaphroditum</i>				lost		lost				lost	lost	absent			absent

Table A2. (continued)

Species	Dominant vascular plant species				Dominant bryophyte species					Dominant lichen species					
	Salher	Vacmyr	Vaculi	Vacvit	Barlyc	Dicfus	Gymcor	Hylspl	Plesch	Clamit	Claran	Claunc	Flaniv	Ochfri	Stespp
<i>Epilobium angustifolium</i>			lost		0 / 0										
<i>Equisetum pratense</i>			0 / 0		0 / -	0 / 0		0 / 0	- / +						
<i>Equisetum scirpoides</i>		0 / -				lost					lost				
<i>Festuca ovina</i>				lost		absent				absent	absent	absent			absent
<i>Festuca vivipara</i>	- / -			lost		+ / +				+ / +	lost	+ / -	+ / +	lost	
<i>Geranium sylvaticum</i>		lost	lost	0 / -	lost	lost		- / -	lost						
<i>Gnaphalium supinum</i>	lost			lost		+ / -				+ / -	+ / -	- / +		lost	- / -
<i>Hierochloë alpina</i>											+ / -				
<i>Hieracium spp.</i>		lost	lost	lost		lost		lost	gained	lost	lost	lost			absent
<i>Huperzia selago ssp. arctica</i>	lost												lost	lost	lost
<i>Juniperus communis</i>		absent	absent	lost		absent		absent	absent	absent	absent	absent			absent
<i>Juncus triglumis</i>			- / +	- / 0		- / 0				- / -	- / 0	+ / -	lost		+ / -
<i>Linnaea borealis</i>		lost	absent	lost		lost		absent	lost	absent	absent	absent			absent
<i>Loiseleuria procumbens</i>			gained								- / 0				+ / -
<i>Luzula confusa</i>	lost														lost
<i>Luzula pilosa</i>			0 / -		0 / -	lost		0 / -	lost						
<i>Luzula spicata</i>	lost		lost			lost		0 / -			lost	lost	lost	lost	- / +
<i>Luzula sudetica</i>				lost		lost			- / 0	+ / -		- / -			
<i>Lycopodium annotinum</i>		absent	absent			lost		absent	lost	absent	absent	absent			absent
<i>Melampyrum pratense</i>			0 / -		lost	lost		0 / +	lost		0 / +				
<i>Melampyrum sylvaticum</i>			lost			+ / 0		+ / 0	lost						
<i>Oxyria digyna</i>								lost		absent				+ / -	
<i>Pedicularis lapponica</i>		lost	lost	lost		lost		lost	lost	lost	lost	lost			lost
<i>Phyllodoce caerulea</i>		0 / +	lost	lost		lost		lost	lost	lost	lost	lost			lost
<i>Poa alpina</i>				lost											
<i>Potentilla crantzii</i>				lost		0 / -									
<i>Pyrola minor</i>			lost			- / +		0 / -	lost						

Table A2. (continued)

Species	Dominant vascular plant species				Dominant bryophyte species					Dominant lichen species					
	Salher	Vacmyr	Vaculi	Vacvit	Barlyc	Dicfus	Gymcor	Hylspl	Plesch	Clamit	Claran	Claunc	Flaniv	Ochfri	Stespp
<i>Salix glauca</i>		lost	lost	lost		lost		lost	gained	lost	+ / +	lost			lost
<i>Salix hastata</i>		absent	gained			absent		absent	gained	absent	absent				
<i>Salix herbacea</i>															+ / 0
<i>Salix polaris</i>	lost														gained
<i>Saussurea alpina</i>			absent	lost		absent		gained	absent	absent	absent	absent			absent
<i>Selaginella selaginoides</i>		- / -	lost	lost		lost		- / +	- / +	- / +	lost	lost			lost
<i>Sibbaldia procumbens</i>	lost			lost		lost					lost	- / 0		- / -	- / 0
<i>Silene acaulis</i>	lost			lost		- / 0				- / 0	lost	- / 0	+ / -	lost	
<i>Solidago virgaurea</i>		lost	lost	lost		lost		lost	lost	lost	absent	absent			gained
<i>Taraxacum spp.</i>	lost			lost		lost		- / -	gained	- / +	lost	lost			
<i>Thalictrum alpinum</i>		0 / +	- / -	lost		0 / -		- / +	lost	lost	- / +				
<i>Trientalis europaea</i>		lost	lost	lost	lost	lost		lost	lost	lost	lost	lost			lost
<i>Trisetum spicatum</i>	lost			lost		lost				+ / 0	- / 0	- / 0		- / 0	- / 0
<i>Trollius europaeus</i>		- / +	lost	0 / -	0 / +	lost		- / -	lost	- / -	lost				
<i>Vaccinium myrtillus</i>			lost	lost		0 / +		lost	lost	lost	lost	absent			absent
<i>Vaccinium uliginosum</i>				lost		absent				absent	absent	absent			absent
<i>Vaccinium vitis-idaea</i>						lost				absent	absent				gained
<i>Viola biflora</i>		- / 0	lost	0 / -		- / -		- / 0	- / +	- / +	- / -	lost			- / +
Subordinate bryophyte species															
<i>Anastrophyllum minutum</i>						- / 0							lost		+ / 0
<i>Andreaea rupestris</i>															0 / 0
<i>Anthelia juratzkana</i>															gained
<i>Aulacomnium turgidum</i>				lost											
<i>Barbilophozia attenuata</i>									lost			0 / -			0 / 0
<i>Barbilophozia sp.</i>		lost	lost		lost	lost		lost	lost	0 / -	0 / +	gained			0 / 0
<i>Barbilophozia hatcheri</i>			lost			- / -				lost	lost	lost			lost
<i>Barbilophozia lycopodioides</i>		lost	lost	lost		lost		lost	lost	lost	lost	absent			lost

Table A2. (continued)

Species	Dominant vascular plant species				Dominant bryophyte species					Dominant lichen species					
	Salher	Vacmyr	Vaculi	Vacvit	Barlyc	Dicfus	Gymcor	Hylspl	Plesch	Clamit	Claran	Claunc	Flaniv	Ochfri	Stespp
<i>Blepharostoma trichophyllum</i>	- / -			- / -		- / -		- / +			- / -	- / -	- / -	lost	
<i>Bryum spp.</i>						- / -				- / 0	lost		- / -		- / -
<i>Conostomum tetragonum</i>	lost														0 / 0
<i>Dicranum elongatum</i>						lost									gained
<i>Dicranum fuscescens</i>															absent
<i>Dicranum scoparium</i>				lost		lost				lost	lost	absent			absent
<i>Dicranum spadiceum</i>	- / -					- / 0							+ / 0	- / -	+ / 0
<i>Diplophyllum taxifolium</i>															absent
<i>Gymnomitrium concinnatum</i>															- / +
<i>Gymnomitrium corallioides</i>	lost					lost				- / 0	0 / 0		lost	lost	0 / 0
<i>Hepaticae spp.</i>			absent	lost		lost		absent	gained	absent	absent	absent			absent
<i>Hylocomium splendens</i>			absent	lost		absent				lost	absent	absent			absent
<i>Lophozia sudetica</i>						+ / -				lost	+ / 0				+ / 0
<i>Pleurocladula albescens</i>	lost					absent					+ / -			lost	
<i>Pleurozium schreberi</i>			absent	lost		lost		absent		lost	absent	absent			absent
<i>Pogonatum dentatum</i>															absent
<i>Pogonatum urnigerum</i>							lost				lost	0 / -			
<i>Pohlia cruda</i>			- / -	lost		- / +		- / +		- / -			0 / -	lost	
<i>Pohlia spp.</i>															- / 0
<i>Pohlia nutans</i>															absent
<i>Polytrichastrum alpinum</i>															gained
<i>Polytrichum commune</i>		lost	absent	lost		absent		absent	lost	absent	absent	absent			absent
<i>Polytrichum hyperboreum</i>															lost
<i>Polytrichum juniperinum</i>			absent	lost		lost		absent	gained	lost	lost	absent			absent
<i>Polytrichum piliferum</i>															+ / 0
<i>Polytrichum sexangulare</i>	lost														
<i>Polytrichum strictum</i>		lost	absent					absent	absent	gained	gained	absent			absent

Table A2. (continued)

Species	Dominant vascular plant species				Dominant bryophyte species					Dominant lichen species					
	Salher	Vacmyr	Vaculi	Vacvit	Barlyc	Dicfus	Gymcor	Hylspl	Plesch	Clamit	Claran	Claunc	Flaniv	Ochfri	Stespp
<i>Ptilidium ciliare</i>				- / 0		lost				lost	lost	lost			absent
<i>Racomitrium lanuginosum</i>															absent
<i>Sanionia uncinata</i>						absent				lost	absent				absent
<i>Sciuro-hypnum reflexum</i>		lost	lost	lost	lost	absent		absent	lost	absent	absent				
<i>Tetralophozia setiformis</i>						- / 0				+ / 0	+ / 0		lost		+ / -
<i>Tritomaria quinquedentata</i>	absent														absent
Subordinate lichen species															
<i>Alectoria ochroleuca</i>	- / 0													lost	+ / 0
<i>Bryocaulon divergens</i>	lost					- / 0								lost	+ / -
<i>Cetraria crispiformis</i>						0 / 0				0 / 0	- / 0		lost	lost	+ / 0
<i>Cetrariella delisei</i>															+ / -
<i>Cetraria ericetorum</i>						+ / 0				- / 0	- / 0				- / 0
<i>Cetraria islandica</i>															absent
<i>Cetraria nigricans</i>	- / 0			lost		- / 0	lost			lost	lost	lost			- / 0
<i>Cladonia bellidiflora</i>				- / -						0 / -	- / -	lost			lost
<i>Cladonia borealis</i>															absent
<i>Cladonia chlorophaea</i>															absent
<i>Cladonia cornuta</i>		lost	absent			lost		absent	lost	lost	lost	absent			absent
<i>Cladonia crispata</i>						lost				lost	lost	absent			absent
<i>Cladonia deformis</i>			absent	lost		lost				lost	lost	absent			absent
<i>Cladonia digitata</i>			absent			absent				absent	absent	absent			absent
<i>Cladonia ecmocyna</i>						gained				lost	lost	lost			lost
<i>Cladonia gracilis</i>						lost									lost
<i>Cladonia maxima</i>			lost		lost	0 / +		lost	lost	0 / -	lost	gained			
<i>Cladonia merochlorophaea</i>			lost	lost		lost				lost	lost	lost			absent
<i>Cladonia mitis</i>						lost									lost
<i>Cladonia pleurota</i>			absent	lost		lost				lost	lost	lost			lost

Table A3. The proportions of best-fit dominant-subordinate species distribution models that retain each explanatory variable, split by the different dominant species. Dom. sp. = Dominant species. Species names given in full in Table A1.

Dominant species	Number of models	Mean deviance explained	Explanatory variables							Any dom. sp. variable
			Altitude	Soil moisture	Soil quality	Dom. sp. cover	Altitude x Dom. sp. cover	Soil moisture x Dom. sp. cover	Soil quality x Dom. sp. cover	
All species	1082	0.32	0.92	0.82	0.85	0.71	0.83	0.80	0.85	> 0.99
Bet nan	25	0.35	0.96	0.92	0.88	0.92	0.88	0.92	0.80	1.00
Car big	17	0.41	0.94	0.71	0.94	0.82	1.00	0.71	1.00	1.00
Cas tet	9	0.45	0.78	1.00	1.00	0.89	0.89	1.00	1.00	1.00
Des fle	14	0.31	0.93	0.93	0.79	0.79	0.93	0.79	0.93	1.00
Emp her	50	0.35	0.88	0.78	0.88	0.74	0.86	0.92	0.94	1.00
Fes ovi	69	0.29	0.93	0.74	0.80	0.74	0.65	0.84	0.87	1.00

Jun ico	8	0.40	0.88	0.88	0.88	0.88	0.75	0.88	1.00	1.00
Lin bor	23	0.35	0.83	0.91	0.83	0.87	0.87	0.70	0.78	1.00
Phy cae	20	0.32	0.95	0.95	0.80	0.70	0.75	0.95	0.70	1.00
Sal her	33	0.37	0.94	0.82	0.82	0.82	0.97	0.91	0.76	1.00
Vac myr	30	0.30	0.87	0.87	0.83	0.57	0.87	0.73	0.90	1.00
Vac uli	65	0.28	0.88	0.80	0.80	0.71	0.75	0.80	0.85	1.00
Vac vit	57	0.30	0.95	0.79	0.89	0.54	0.86	0.72	0.77	1.00
Bar lyc	15	0.38	0.80	0.93	0.87	0.67	0.87	0.93	0.80	1.00
Dic fus	108	0.31	0.92	0.82	0.84	0.65	0.83	0.76	0.87	1.00
Gym cor	3	0.51	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Hyl spl	55	0.32	0.98	0.84	0.89	0.71	0.69	0.82	0.84	1.00
Ple sch	49	0.30	0.84	0.82	0.94	0.59	0.92	0.73	0.84	1.00
Cla mit	88	0.32	0.95	0.91	0.83	0.78	0.82	0.86	0.91	1.00
Cla ran	97	0.29	0.90	0.84	0.87	0.61	0.80	0.85	0.79	0.99
Cla unc	70	0.29	0.96	0.79	0.81	0.77	0.87	0.73	0.84	1.00

Fla niv	29	0.39	0.97	0.76	0.90	0.79	0.93	0.76	0.90	1.00
Och fri	32	0.39	0.94	0.75	0.91	0.84	0.97	0.78	0.94	1.00
Ste spp	116	0.29	0.93	0.81	0.81	0.67	0.81	0.75	0.82	0.99

Table A4. The number of subordinate species exhibiting different changes in range extent and upper and lower range limits when comparing low and high dominant species cover. Only subordinate species that were predicted to be present under both low and high dominant species cover were considered. *Gymnomitrion corallioides* is absent from the list of dominant species because none of the subordinate species that were adequately sampled were predicted to be present under both low and high cover of this dominant. Species names given in full in Table A1.

Dominant species	Range extent			Range limits								
	No change	Net expansion	Net contraction	No change	Both expand	Both contract	Upper expand	Upper contract	Lower expand	Lower contract	Upper expand & lower contract	Upper contract & lower expand
Bet nan	1	2	4	1	0	2	3	1	0	0	0	0
Car big	0	1	3	0	0	1	1	0	0	2	0	0
Cas tet	0	0	5	0	0	1	0	1	0	3	0	0
Des fle	0	2	1	0	0	0	1	1	0	0	1	0

Emp her	1	1	6	1	0	2	0	2	0	1	0	2
Fes ovi	4	5	12	4	1	5	2	6	1	1	1	0
Jun ico	1	0	2	1	0	0	0	2	0	0	0	0
Lin bor	1	2	2	1	1	0	1	1	0	0	1	0
Phy cae	0	0	5	0	0	2	0	1	0	1	0	1
Sal her	0	0	7	0	0	3	0	1	0	3	0	0
Vac myr	0	4	5	0	0	1	2	2	1	2	1	0
Vac uli	3	3	10	3	2	2	0	6	1	2	0	0
Vac vit	0	0	11	0	0	3	0	3	0	3	2	0
Bar lyc	3	1	2	3	0	0	1	2	0	0	0	0
Dic fus	5	9	24	5	1	5	4	7	2	9	1	4
Gym cor	0	0	0	0	0	0	0	0	0	0	0	0
Hyl spl	6	3	15	6	0	5	1	4	1	1	6	0
Ple sch	1	1	8	2	0	1	0	0	0	2	5	0
Cla mit	3	9	19	3	1	3	2	4	4	9	3	2

Cla ran	4	9	16	3	3	5	2	1	4	7	1	3
Cla unc	3	0	12	1	0	4	0	2	0	4	2	2
Fla niv	0	3	4	0	2	2	0	1	1	0	0	1
Och fri	0	2	7	0	0	3	0	0	0	3	1	2
Ste spp	5	21	18	5	3	3	1	1	10	7	6	8
Total	41	78	198	39	14	53	21	49	25	60	31	25
Total (%)	13 %	25 %	62 %	12 %	4 %	17 %	7 %	15 %	8 %	19 %	10 %	8 %

Table A5. The relationship between species traits and the impact of high dominant species cover on subordinate species altitudinal distribution. DE = proportion of deviance explained, dom. spp. = dominant species, subord. spp. = subordinate species, Plant group = lichen, bryophyte or vascular plant species, CSR classification = Grime's (1977) seven class classification, Simplified CSR classification = a three class simplification of Grime's (1977) CSR classification that was implemented due to the scarcity of ruderal species in this study, * = significant after Bonferroni correction.

Altitudinal distribution					
characteristic	Species trait	DE	F	n	p
Effect on subordinate species lower altitudinal limit	Plant group: dom. spp.	< 0.01	0.14	317	0.872
	Plant group: subord. spp.	0.03	4.38	317	0.013
altitudinal limit	CSR classification: dom. spp.	0.01	1.03	104	0.314
	CSR classification: subord. spp.	0.11	4.40	187	< 0.001*
	Simplified CSR classification: dom. spp.	0.01	1.03	104	0.314
	Simplified CSR classification: subord. spp.	< 0.01	0.37	187	0.693
	Growth form group: dom. spp.	< 0.01	0.23	104	0.799
	Growth form group: subord. spp.	0.03	1.16	187	0.332
	Species occurrences: dom. spp.	< 0.01	0.05	317	0.828
	Species occurrences: subord. spp.	< 0.01	1.21	317	0.271
	Mean cover where present: dom. spp.	< 0.01	0.04	317	0.840
	Mean cover where present: subord. spp.	< 0.01	0.27	317	0.602
	Altitudinal range: dom. spp.	0.01	4.41	317	0.037
	Altitudinal range: subord. spp.	< 0.01	0.00	317	0.966

	Altitudinal mid-point: dom. spp.	< 0.01	0.74	317	0.389
	Altitudinal mid-point: subord. spp.	< 0.01	0.03	317	0.873
	Altitudinal median: dom. spp.	0.01	3.68	317	0.056
	Altitudinal median: subord. spp.	< 0.01	0.29	317	0.590
	Arctic-alpine distribution: dom. spp.	0.02	4.89	317	0.028
	Arctic-alpine distribution: subord. spp.	< 0.01	0.71	317	0.399
Effect on subordinate	Plant group: dom. spp.	< 0.01	1.02	317	0.363
species upper	Plant group: subord. spp.	< 0.01	0.09	317	0.911
altitudinal limit	CSR classification: dom. spp.	< 0.01	0.61	104	0.435
	CSR classification: subord. spp.	0.02	0.56	187	0.730
	Simplified CSR classification: dom. spp.	< 0.01	0.61	104	0.435
	Simplified CSR classification: subord. spp.	< 0.01	0.74	187	0.477
	Growth form group: dom. spp.	0.01	0.66	104	0.521
	Growth form group: subord. spp.	0.02	0.88	187	0.477
	Species occurrences: dom. spp.	< 0.01	0.87	317	0.353
	Species occurrences: subord. spp.	0.02	4.80	317	0.029
	Mean cover where present: dom. spp.	< 0.01	1.69	317	0.195
	Mean cover where present: subord. spp.	0.02	4.92	317	0.027
	Altitudinal range: dom. spp.	< 0.01	0.17	317	0.676
	Altitudinal range: subord. spp.	< 0.01	0.85	317	0.358
	Altitudinal mid-point: dom. spp.	< 0.01	0.03	317	0.870
	Altitudinal mid-point: subord. spp.	< 0.01	1.71	317	0.192
	Altitudinal median: dom. spp.	< 0.01	0.85	317	0.357

	Altitudinal median: subord. spp.	< 0.01	0.22	317	0.642
	Arctic-alpine distribution: dom. spp.	< 0.01	1.21	317	0.272
	Arctic-alpine distribution: subord. spp.	< 0.01	0.01	317	0.919
Effect on subordinate	Plant group: dom. spp.	< 0.01	0.39	317	0.677
species altitudinal	Plant group: subord. spp.	0.02	3.69	317	0.026
range	CSR classification: dom. spp.	0.02	2.35	104	0.128
	CSR classification: subord. spp.	0.08	2.97	187	0.013
	Simplified CSR classification: dom. spp.	0.02	2.35	104	0.128
	Simplified CSR classification: subord. spp.	< 0.01	0.03	187	0.974
	Growth form group: dom. spp.	0.02	1.25	104	0.291
	Growth form group: subord. spp.	0.05	2.64	187	0.035
	Species occurrences: dom. spp.	< 0.01	0.01	317	0.916
	Species occurrences: subord. spp.	0.03	10.80	317	0.001*
	Mean cover where present: dom. spp.	< 0.01	2.02	317	0.156
	Mean cover where present: subord. spp.	0.01	3.98	317	0.047
	Altitudinal range: dom. spp.	0.02	6.08	317	0.014
	Altitudinal range: subord. spp.	< 0.01	0.38	317	0.536
	Altitudinal mid-point: dom. spp.	< 0.01	1.16	317	0.283
	Altitudinal mid-point: subord. spp.	< 0.01	0.45	317	0.502
	Altitudinal median: dom. spp.	0.02	5.41	317	0.021
	Altitudinal median: subord. spp.	< 0.01	0.16	317	0.691
	Arctic-alpine distribution: dom. spp.	0.03	10.18	317	0.002*
	Arctic-alpine distribution: subord. spp.	< 0.01	0.45	317	0.504
