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, wide-spread 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						
Betula nana	Bet nan	327	4.7	15.4	514	boreal
Carex bigelowii	Car big	172	0.5	3.2	517	arctic-alpine
Cassiope tetragona	Cas tet	205	1.1	5.6	551	arctic-alpine
Deschampsia flexuosa	Des fle	349	2.0	6.1	456	boreal
Empetrum nigrum ssp. *hermaphroditum*	Emp her	671	14.2	22.9	562	boreal
Festuca ovina	Fes ovi	292	0.5	1.9	562	boreal
Juniperus communis	Jun ico	139	2.1	16.0	401	boreal
Linnaea borealis	Lin bor	321	0.7	2.3	456	boreal
Phyllodoce caerulea	Phy cae	168	0.8	5.2	483	arctic-alpine
Salix herbacea	Sal her	178	0.6	3.9	762	arctic-alpine

Vaccinium myrtillus	Vac myr	362	4.7	14.2	511	boreal
Vaccinium uliginosum	Vac uli	312	2.6	8.9	562	boreal
Vaccinium vitis-idaea	Vac vit	716	4.1	6.1	581	boreal
Dominant bryophyte species						
Barbilophozia lycopodioides	Bar lyc	311	0.9	3.1	403	boreal
Dicranum fuscescens	Dic fus	556	2.0	3.9	652	boreal
Gymnomitrion corallioides	Gym cor	111	0.7	6.4	472	arctic-alpine
Hylocomium splendens	Hyl spl	297	2.7	9.8	546	boreal
Pleurozium schreberi	Ple sch	336	3.1	9.9	535	boreal
Dominant lichen species						
Cladonia mitis	Cla mit	549	1.0	2.0	628	boreal
Cladonia rangiferina	Cla ran	458	0.6	1.5	628	boreal
Cladonia uncialis	Cla unc	349	0.6	1.9	581	boreal
Flavocetraria nivalis	Fla niv	255	0.6	2.5	634	arctic-alpine
Ochrolechia frigida	Och fri	232	0.9	4.3	608	boreal
Stereocaulon spp.	Ste spp	283	0.6	2.4	899	boreal

[1] In 1080 1 m^2 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 i 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
Subordinate vascular plant species												
Alchemilla spp.	20	248	boreal									- / -
Antennaria alpina	45	410	arctic-alpine		lost	- / 0		lost	- / -			
Antennaria dioica	31	301	boreal				0 / +			0 / -	0 / +	
Anthoxanthum odoratum ssp. alpinum	76	403	arctic-alpine	lost			- / +	lost	lost		lost	lost
Arctostaphylos alpina	32	390	arctic-alpine									
Astragalus alpinus	42	491	arctic-alpine					0 / -	lost			
Bartsia alpina	30	403	arctic-alpine	- / -								lost
Betula pubescens ssp. czerepanovii	57	204	boreal	lost			lost		lost	absent	absent	absent
Betula nana	327	514	boreal					- / -	lost			
Bistorta vivipara	149	445	boreal		lost			lost	lost			
Calamagrostis lapponica	229	550	boreal					lost	absent			
Campanula rotundifolia	53	481	boreal	0 / -				0 / -	0 / -			
Carex bigelowii	172	517	arctic-alpine									
Carex lachenalii	31	314	arctic-alpine			0 / -			0 / -			
Carex vaginata	143	518	boreal					lost	lost			
Cassiope hypnoides	69	451	arctic-alpine			lost						
Cassiope tetragona	205	551	arctic-alpine									
Cornus suecica	87	172	boreal	0 / 0					0 / 0		0 / 0	
Deschampsia flexuosa	349	456	boreal					lost	absent		lost	
Diapensia lapponica	53	463	arctic-alpine						- / -			
Diphasiastrum alpinum	28	382	arctic-alpine	lost	lost			lost	+ / 0			- / 0
Dryas octopetala	45	442	arctic-alpine			absent						
Empetrum nigrum spp. hermaphroditum	671	562	boreal									

Table A2. (continued)

Species	Occurrences	Altitudinal range (m)	Biogeographic distribution	Dominant vascular plant species								
				Betnan	Carbig	Castet	Desfle	Empher	Fesovi	Junico	Linbor	Phycae
Epilobium angustifolium	26	210	boreal					lost	0 / 0	0 / -	lost	
Equisetum pratense	35	240	boreal					lost	0 / 0	0 / 0	0 / -	lost
Equisetum scirpoides	28	389	arctic-alpine	- / +			0 / -		0 / -			
Festuca ovina	292	562	boreal									
Festuca vivipara	46	386	arctic-alpine		- / -	lost		lost	lost			
Geranium sylvaticum	68	211	boreal	lost				lost	0 / -	lost	absent	lost
Gnaphalium supinum	41	410	arctic-alpine		lost			lost	0 / -			
Hierochloë alpina	23	453	boreal									
Hieracium spp.	122	481	boreal	lost				lost	lost			lost
Huperzia selago ssp. arctica	111	577	boreal									
Juniperus communis	139	401	boreal	absent			absent	lost	absent		absent	absent
Juncus triglumis	128	497	arctic-alpine					+ / -	- / -			
Linnaea borealis	321	456	boreal					lost	absent			
Loiseleuria procumbens	30	427	arctic-alpine	lost								
Luzula confusa	104	585	arctic-alpine									
Luzula pilosa	30	162	boreal							lost		
Luzula spicata	33	358	arctic-alpine		absent			lost	lost			
Luzula sudetica	23	350	boreal									- / +
Lycopodium annotinum	92	468	boreal	absent					absent			
Melampyrum pratense	61	146	boreal						0 / +		lost	
Melampyrum sylvaticum	30	147	boreal						+ / +	lost	- / +	
Oxyria digyna	34	295	arctic-alpine		lost	- / -						
Pedicularis lapponica	141	481	boreal	lost				lost	lost			
Phyllodoce caerulea	168	483	arctic-alpine	lost				lost	lost			
Poa alpina	25	428	arctic-alpine		lost				0 / -			
Potentilla crantzii	24	318	boreal		0 / +							
Pyrola minor	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
Salix glauca	63	403	boreal	lost			absent		lost		lost	absent
Salix hastata	37	390	boreal	absent					lost			absent
Salix herbacea	178	762	arctic-alpine									
Salix polaris	105	695	arctic-alpine									
Saussurea alpina	82	483	arctic-alpine					lost	lost			
Selaginella selaginoides	48	403	boreal	lost				lost	lost			lost
Sibbaldia procumbens	33	410	arctic-alpine									
Silene acaulis	34	363	arctic-alpine		lost	- / 0		lost	lost			
Solidago virgaurea	230	401	boreal	lost			lost	lost	lost		absent	
Taraxacum spp.	35	377	boreal		lost				lost			lost
Thalictrum alpinum	49	376	arctic-alpine	- / +	lost			- / -	- / -			0 / -
Trientalis europaea	145	376	boreal				lost	lost	lost		lost	
Trisetum spicatum	32	433	arctic-alpine		lost				lost			
Trollius europaeus	53	296	boreal	lost				lost	lost	lost	lost	lost
Vaccinium myrtillus	362	511	boreal					lost	absent			
Vaccinium uliginosum	312	562	boreal									
Vaccinium vitis-idaea	716	581	boreal									
Viola biflora	113	431	arctic-alpine	lost				lost	lost			lost
Subordinate bryophyte species												
Anastrophyllum minutum	132	569	boreal									
Andreaea rupestris	157	527	boreal									
Anthelia juratzkana	111	792	arctic-alpine									
Aulacomnium turgidum	20	398	arctic-alpine									
Barbilophozia attenuata	33	420	boreal	0 / +			lost					
Barbilophozia sp.	40	253	boreal	0 / +			lost				lost	
Barbilophozia hatcheri	87	527	boreal					lost	lost			
Barbilophozia lycopodioides	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
Blepharostoma trichophyllum	27	300	boreal		lost	lost						+ / -
Bryum spp.	47	521	boreal									
Conostomum tetragonum	49	692	arctic-alpine									
Dicranum elongatum	41	635	arctic-alpine									
Dicranum fuscescens	556	652	boreal									
Dicranum scoparium	251	567	boreal									
Dicranum spadiceum	53	387	arctic-alpine			- / 0						
Diplophyllum taxifolium	61	763	boreal									
Gymnomitrion concinnatum	165	628	arctic-alpine									
Gymnomitrion corallioides	111	472	arctic-alpine		- / 0							
Hepaticae spp.	141	529	boreal					lost	absent			
Hylocomium splendens	297	546	boreal					lost	absent			
Lophozia sudetica	85	533	boreal									
Pleurocladula albescens	29	465	arctic-alpine		lost							
Pleurozium schreberi	336	535	boreal					lost	absent			
Pogonatum dentatum	88	796	arctic-alpine									
Pogonatum urnigerum	25	263	boreal					absent				
Pohlia cruda	33	434	boreal					lost	- / -			
Pohlia spp.	63	685	boreal									
Pohlia nutans	140	858	boreal									
Polytrichastrum alpinum	101	747	arctic-alpine									
Polytrichum commune	206	403	boreal				lost	lost	absent		lost	
Polytrichum hyperboreum	147	869	arctic-alpine									
Polytrichum juniperinum	229	534	boreal					lost	absent			
Polytrichum piliferum	108	773	boreal									
Polytrichum sexangulare	26	576	arctic-alpine									
Polytrichum strictum	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
Ptilidium ciliare	285	562	boreal									
Racomitrium lanuginosum	139	756	boreal									
Sanionia uncinata	103	575	boreal									
Sciuro-hypnum reflexum	76	339	boreal				lost	lost	absent		absent	
Tetralophozia setiformis	103	562	boreal									
Tritomaria quinquedentata	54	754	boreal									
Subordinate lichen species												
Alectoria ochroleuca	107	599	arctic-alpine									
Bryocaulon divergens	87	551	arctic-alpine									
Cetraria crispiformis	262	519	boreal									
Cetrariella delisei	61	656	boreal									
Cetraria ericetorum	137	579	boreal									
Cetraria islandica	115	819	boreal									
Cetraria nigricans	42	441	arctic-alpine									
Cladonia bellidiflora	87	531	boreal									
Cladonia borealis	127	645	boreal									
Cladonia chlorophaea	112	652	boreal									
Cladonia cornuta	65	486	boreal						absent			
Cladonia crispata	85	576	boreal									
Cladonia deformis	94	534	boreal					lost	absent			
Cladonia digitata	122	558	boreal					absent	absent			
Cladonia ecmocyna	52	550	boreal									
Cladonia gracilis	521	628	boreal									
Cladonia maxima	46	376	boreal						lost		lost	
Cladonia merochlorophaea	119	521	boreal					lost	- / 0			
Cladonia mitis	549	628	boreal									
Cladonia pleurota	207	551	boreal					lost	absent			

Table A2. (continued)

Species	Occurrences	Altitudinal range (m)	Biogeographic distribution	Dominant vascular plant species								
				Betnan	Carbig	Castet	Desfle	Empher	Fesovi	Junico	Linbor	Phycae
Cladonia pyxidata	203	583	boreal									
Cladonia rangiferina	458	628	boreal									
Cladonia squamosa	28	504	boreal						absent			
Cladonia stellaris	35	363	boreal	absent							absent	absent
Cladonia subfurcata	35	528	arctic-alpine									
Cladonia sulphurina	176	567	boreal									
Cladonia symphycarpa	25	343	boreal					lost				
Cladonia uncialis	349	581	boreal									
Crustose lichen	92	469	boreal		- / 0			- / 0	absent			
Flavocetraria cucullata	283	533	arctic-alpine									
Flavocetraria nivalis	255	634	arctic-alpine									
Gowardia nigricans	116	551	arctic-alpine									
Nephroma arcticum	132	534	boreal						absent			
Ochrolechia frigida	232	608	boreal									
Peltigera apthosa	87	456	boreal						lost			
Peltigera leucophlebia	32	442	boreal					lost				
Peltigera malacea	46	475	boreal						absent			
Peltigera polydactyla	21	379	boreal	gained								
Peltigera rufescens	28	438	boreal					0 / 0	0 / 0			
Peltigera scabrosa	33	415	boreal						lost		+ / +	
Pertusaria dactylina	172	608	arctic-alpine									
Pseudephebe pubescens	38	439	arctic-alpine									
Psoroma hypnorum	36	445	boreal					+ / -	- / +			
Solorina crocea	84	499	arctic-alpine									
Sphaerophorus globosus	155	560	arctic-alpine									
Thamnolia vermicularis	119	549	arctic-alpine									
Umbilicaria spp.	65	452	boreal									

Table A2. (continued)

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

Table A2. (continued)

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

Table A2. (continued)

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

Table A2. (continued)

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

Table A2. (continued)

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

Table A2. (continued)

	Dominant vascular plant species				Dominant bryophyte species					Dominant lichen species					
Species	Salher	Vacmyr	Vaculi	Vacvit	Barlyc	Dicfus	Gymcor	Hylspl	Plesch	Clamit	Claran	Claunc	Flaniv	Ochfri	Stespp
Cladonia pyxidata						lost				- / 0	lost				lost
Cladonia rangiferina						lost									absent
Cladonia squamosa			absent							lost	lost				
Cladonia stellaris			gained						absent						absent
Cladonia subfurcata						+ / -					+ / +		lost		+ / 0
Cladonia sulphurina				lost		lost				lost	absent	lost			absent
Cladonia symphycarpa						0 / -				lost	lost				
Cladonia uncialis						lost				+ / 0	+ / +				absent
Crustose lichen	lost		- / 0	lost		lost				- / 0	- / 0	lost	lost	- / 0	+ / 0
Flavocetraria cucullata	lost					- / 0				- / 0	- / 0		+ / +	lost	+ / -
Flavocetraria nivalis															lost
Gowardia nigricans	lost					0 / 0								lost	lost
Nephroma arcticum			gained			lost		lost	lost	lost	lost	lost			absent
Ochrolechia frigida													lost		+ / -
Peltigera apthosa		lost	lost			lost		lost	lost	lost	lost	lost			absent
Peltigera leucophlebia			lost			0 / -		0 / 0	- / +	lost	lost	lost			
Peltigera malacea			absent						absent		absent	absent			absent
Peltigera polydactyla					gained			absent	lost			lost			
Peltigera rufescens			0 / 0			0 / -		0 / 0		0 / 0	0 / 0	0 / 0			
Peltigera scabrosa		lost	- / 0					- / -	- / -		- / -	- / -			- / -
Pertusaria dactylina													lost		+ / +
Pseudephebe pubescens	lost			lost		+ / -	lost			+ / 0	+ / 0	lost			
Psoroma hypnorum	lost		+ / +	- / -		lost		0 / 0			- / -	- / 0	lost	+ / -	+ / +
Solorina crocea						lost				lost	lost		lost	lost	+ / 0
Sphaerophorus globosus						lost							lost	lost	lost
Thamnolia vermicularis	lost												lost	lost	+ / -
Umbilicaria spp.															0 / -

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.

			Explanatory variables							
Dominant species	Number of models	Mean deviance explained	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	Any dom. sp. variable
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.

	Range extent			Range limits								
Dominant species	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
	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 species upper altitudinal limit	Plant group: dom. spp.	< 0.01	1.02	317	0.363
	Plant group: subord. spp.	< 0.01	0.09	317	0.911
	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 species altitudinal range	Plant group: dom. spp.	< 0.01	0.39	317	0.677
	Plant group: subord. spp.	0.02	3.69	317	0.026
	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