

Appendix 1

Notes on species identification and species list

We identified all species at species level, except those that cannot be reliably identified (*Alchemilla* spp., *Taraxacum* spp., *Cladonia chlorophaea* section, *Lepraria* spp.). We included the most abundant liverwort (*Ptilidium ciliare*) in moss species. We excluded mosses and lichens that grow on rock surfaces, because they are affected by other environmental variables. We followed the taxonomy of Hämet-Ahti et al. (1998) for vascular plants, Laine et al. (2011), Hallinbäck et al. (2006, 2008), and Hedenäs and Hallinbäck (2014) for mosses, and Stenroos et al. (2011) for lichens.

Hallinbäck T. et al. 2006. Nationalnyckeln till Sveriges flora och fauna. Bladmossor: sködmossor–blåmossor. Bryophyta: Buxbaumia–Leucobryum. – ArtDatabanken, SLU.

Hallinbäck T. et al. 2008. Nationalnyckeln till Sveriges flora och fauna. Bladmossor: kompaktmossor–kapmossor. Bryophyta: Anoetangium–Orthodontium. – ArtDatabanken, SLU.

Hedenäs L. Hallinbäck T. 2014. Nationalnyckeln till sveriges flora och fauna, Bladmossor: Skirmossor–Baronmossor. Bryophyta: Hookeria–Anomodon. – ArtDatabanken, SLU.

Hämet-Ahti L. et al. 1998. Retkeilykasvio (Field Flora of Finland). – Finnish Museum of Natural History, Botanical Museum.

Laine J. et al. 2011. The intricate beauty of Sphagnum mosses – a finnish guide to identification. – Univ. of Helsinki, Dept of Forest Sciences.

Stenroos S. et al. 2011. Suomen jäkäläopas. – Luonnontieteellisen keskusmuseon kasvimuseo.

The species list contains species with \geq eight observations, all together 153 species (69 vascular plant, 30 moss, and 54 lichen species), of which *Empetrum hermaphroditum* was used as a predictor.

Abbreviation	Species name	Taxonomical group	Observations	Abbreviation	Species name	Taxonomical group	Observations
VACVIT	<i>Vaccinium vitis-idaea</i>	Vascular plant	344	PSOHYP	<i>Psoroma hypnorum</i>	Lichen	35
EMRHER	<i>Empetrum hermaphroditum</i>	Vascular plant	335	POLLON	<i>Polytrichum longisetum</i>	Moss	34
BETNAN	<i>Betula nana</i>	Vascular plant	278	FOAALP	<i>Poa alpina</i>	Vascular plant	34
CLAMIT	<i>Gadonia mitis</i>	Lichen	257	DIALAP	<i>Diapensia lapponica</i>	Vascular plant	34
FESOV1	<i>Festuca ovina</i>	Vascular plant	246	CASHYP	<i>Cassiope hypnoides</i>	Vascular plant	34
CARBIG	<i>Carex bigelowii</i>	Vascular plant	215	PELMAL	<i>Peltigera malacea</i>	Lichen	33
CETER1	<i>Cetraria ericetorum</i>	Lichen	205	SBPFR0	<i>Sibbaldia procumbens</i>	Vascular plant	32
FLACUC	<i>Flavoctraria cucullata</i>	Lichen	203	DICMAJ	<i>Dicranum majus</i>	Moss	32
DICSCO	<i>Dicranum scoparium</i>	Moss	195	CAMROT	<i>Campanula rotundifolia</i>	Vascular plant	32
POLJUN	<i>Polytrichum juniperinum</i>	Moss	191	HIEALP	<i>Hierochloë alpina</i>	Vascular plant	31
VACULJ	<i>Vaccinium uliginosum</i>	Vascular plant	183	ARCUVA	<i>Arctostaphylos uva-ursi</i>	Vascular plant	31
PTICUL	<i>Ptilidium ciliare</i>	Liverwort	179	TREJUR	<i>Trientalis europaea</i>	Vascular plant	29
CLAPLE	<i>Gadonia pleurota</i>	Lichen	178	BARALP	<i>Bartsia alpina</i>	Vascular plant	29
DICELO	<i>Dicranum elongatum</i>	Moss	175	RANACR	<i>Ranunculus acris</i>	Vascular plant	28
STERALP	<i>Stereocaulon alpinum</i>	Lichen	169	VERALP	<i>Veronica alpina</i>	Vascular plant	27
DICRUS	<i>Dicranum fuscescens</i>	Moss	169	SALMYD	<i>Salix myrtilloides</i>	Vascular plant	27
CLAJNC	<i>Gadonia uncialis</i>	Lichen	160	HUPARC	<i>Huperzia selago</i>	Vascular plant	27
BISIV1	<i>Bistorta vivipara</i>	Vascular plant	159	CETNIG	<i>Cetraria nigricans</i>	Lichen	27
CLAMAX	<i>Gadonia maxima</i>	Lichen	152	PELRUF	<i>Peltigera rufescens</i>	Lichen	26
CALLAP	<i>Calamagrostis lapponica</i>	Vascular plant	147	DRYOCT	<i>Dryas octopetala</i>	Vascular plant	26
SALHER	<i>Salix herbacea</i>	Vascular plant	144	DICORI	<i>Dicranoweisia crispula</i>	Moss	25
SOLMIR	<i>Solidago virgaurea</i>	Vascular plant	143	POLALP	<i>Polytrichastrum alpinum</i>	Moss	24
HYLSPL	<i>Hylocomium splendens</i>	Moss	135	TARSPF	<i>Taraxacum</i> spp.	Vascular plant	23
RHYCAE	<i>Rhizocarpon caeruleum</i>	Vascular plant	133	SILACA	<i>Slime aculis</i>	Vascular plant	23
PARAMB	<i>Parmeliopsis ambigua</i>	Lichen	133	SANUNC	<i>Sanionia uncinata</i>	Moss	23
VACMYR	<i>Vaccinium myrtillus</i>	Vascular plant	132	SALGLA	<i>Salix glauca</i>	Vascular plant	23
LINBOR	<i>Linnaea borealis</i>	Vascular plant	129	LUZCON	<i>Luzula confusa</i>	Vascular plant	22
CLAGRA	<i>Gadonia gracilis</i>	Lichen	129	CLABOR	<i>Gadonia borealis</i>	Lichen	22
CETSEP	<i>Cetraria sepiccola</i>	Lichen	126	CETDEL	<i>Cetrariella delisei</i>	Lichen	22
OCHFR1	<i>Ochrolechia frigida</i>	Lichen	125	ANTDIO	<i>Antennaria dioica</i>	Vascular plant	22
JUNTRF	<i>Juncus trifidus</i>	Vascular plant	125	STECUM	<i>Stereocaulon cumulatum</i>	Lichen	21
POLRIL	<i>Polytrichum piliferum</i>	Moss	120	PYRMIN	<i>Pyrota minor</i>	Vascular plant	21
POHNUT	<i>Pohlia nutans</i>	Moss	119	CNEALP	<i>Cnestrum alpestre</i>	Moss	21
DESFL1	<i>Deschampsia flexuosa</i>	Vascular plant	116	SELSEL	<i>Selaginella selaginoides</i>	Vascular plant	20
FLANIV	<i>Flavoctraria nivalis</i>	Lichen	112	ANDRUP	<i>Andreaea rupestris</i>	Moss	20
FLESCH	<i>Fleurotzium schreberi</i>	Moss	105	RAQLAN	<i>Racomitrium lanuginosum</i>	Moss	17
FEDLAP	<i>Pedicularis lapponica</i>	Vascular plant	104	POLCOM	<i>Polytrichum commune</i>	Moss	17
PARHYP	<i>Parmeliopsis hyperopta</i>	Lichen	100	PELCAN	<i>Peltigera canina</i>	Lichen	17
HIERAC	<i>Hieracium</i> spp.	Vascular plant	97	EQUFRA	<i>Equisetum pratense</i>	Vascular plant	17
HYPFHY	<i>Hypogymnia physodes</i>	Lichen	95	CLASUL	<i>Gadonia sulphurina</i>	Lichen	17
CLACHL	<i>Gadonia chlorophaea</i>	Lichen	95	RHIFEE	<i>Rhizomnium pseudopunctatum</i>	Moss	16
CLARAN	<i>Gadonia rangiferina</i>	Lichen	91	MINIBLY	<i>Mnium blyttii</i>	Moss	15
SFHGLA	<i>Sphaerophorus globosus</i>	Lichen	79	LOIFRO	<i>Loiseleuria procumbens</i>	Vascular plant	15
CLABEL	<i>Gadonia bellidiflora</i>	Lichen	76	ICMERR	<i>Imadophila ericetorum</i>	Lichen	15
THAVER	<i>Thamnia vermicularis</i>	Lichen	74	CLATRA	<i>Gadonia trassii</i>	Lichen	15
BRIDIV	<i>Bryocaulon divergens</i>	Lichen	74	SALPOL	<i>Salix polaris</i>	Vascular plant	14
PELSCA	<i>Peltigera scabrosa</i>	Lichen	72	POHCRU	<i>Pohlia cruda</i>	Moss	14
LEPSP	<i>Leparia</i> spp.	Lichen	72	CONTET	<i>Conostomum tetragonum</i>	Moss	14
VIQBIF	<i>Viola biflora</i>	Vascular plant	71	SALHAS	<i>Salix hastata</i>	Vascular plant	13
JUNICO	<i>Juniperus communis</i>	Vascular plant	70	GEFSYL	<i>Geranium sylvaticum</i>	Vascular plant	13
RELAPH	<i>Peltigera aphthosa</i>	Lichen	69	CLACEN	<i>Gadonia cenotea</i>	Lichen	13
CETISL	<i>Cetraria islandica</i> ssp. <i>islandica</i>	Lichen	69	ANDPOL	<i>Andromeda polifolia</i>	Vascular plant	13
ASTALP	<i>Astragalus alpinus</i>	Vascular plant	68	OCHSP	<i>Ochrolechia</i> sp.	Lichen	12
ARCALP	<i>Arctostaphylos alpina</i>	Vascular plant	68	CLACAR	<i>Gadonia carneola</i>	Lichen	12
GOVNI1	<i>Gowardia nigricans</i>	Lichen	67	ANTCAN	<i>Antennaria canescens</i>	Vascular plant	12
CLAFIM	<i>Gadonia fimbriata</i>	Lichen	66	ALESAR	<i>Alectoria sarmentosa</i>	Lichen	12
CLAFRB	<i>Gadonia arbuscula</i>	Lichen	61	DRADAU	<i>Draba daurica</i>	Vascular plant	11
SALIALP	<i>Saussurea alpina</i>	Vascular plant	58	DICMON	<i>Dicranum montanum</i>	Moss	11
POLHYP	<i>Polytrichum hyperboreum</i>	Moss	57	ALCHEM	<i>Alchemilla</i> spp.	Vascular plant	11
ANTALP	<i>Antennaria alpina</i>	Vascular plant	57	SPHCAP	<i>Sphagnum capillifolium</i>	Moss	10
NEPARC	<i>Nephroma arcticum</i>	Lichen	56	MINBIF	<i>Minuartia biflora</i>	Vascular plant	10
SOLORO	<i>Solorina crocea</i>	Lichen	54	EUFPR1	<i>Euphrasia frigida</i>	Vascular plant	10
LYCALP	<i>Lycopodium annotinum</i>	Vascular plant	51	CLAPYX	<i>Gadonia pyxidata</i>	Lichen	10
RHYRUG	<i>Rhytidium rugosum</i>	Moss	50	SOISTA	<i>Sclero-hyprum starkei</i>	Moss	9
ANTXAL	<i>Anthoxanthum alpinum</i>	Vascular plant	50	SALRET	<i>Salix reticulata</i>	Vascular plant	9
THAALP	<i>Thalictrum alpinum</i>	Vascular plant	48	RHOROS	<i>Rhodiola rosea</i>	Vascular plant	9
CASTET	<i>Cassiope tetragona</i>	Vascular plant	48	POGDEN	<i>Pogonatum dentatum</i>	Moss	9
GNASUP	<i>Gnaphalium supinum</i>	Vascular plant	47	NEPPAR	<i>Nephroma parile</i>	Lichen	9
CLAMAM	<i>Gadonia amaurocrea</i>	Lichen	45	CLASUB	<i>Gadonia subulata</i>	Lichen	9
ALECOH	<i>Alectoria ochroleuca</i>	Lichen	43	CLAMET	<i>Gadonia metacorrallifera</i>	Lichen	9
EQUUSCI	<i>Equisetum scirpoides</i>	Vascular plant	39	AULTUR	<i>Aulacomnium turgidum</i>	Moss	9
CLADEF	<i>Gadonia deformis</i>	Lichen	39	NEPEXP	<i>Nephroma expallidum</i>	Lichen	8
POTORA	<i>Potentilla crantzii</i>	Vascular plant	38	LYCHAL	<i>Viscaria alpina</i>	Vascular plant	8
CETCRI	<i>Cetraria islandica</i> ssp. <i>crispiformis</i>	Lichen	38	ERUNI	<i>Erigeron uniflorus</i>	Vascular plant	8
DIPALP	<i>Diphysastrum alpinum</i>	Vascular plant	37	CLASTR	<i>Gadonia stricta</i>	Lichen	8
CARVAG	<i>Carex vaginata</i>	Vascular plant	37	BETCZE	<i>Betula pubescens</i>	Vascular plant	8
CARRUP	<i>Carex rupestris</i>	Vascular plant	36				

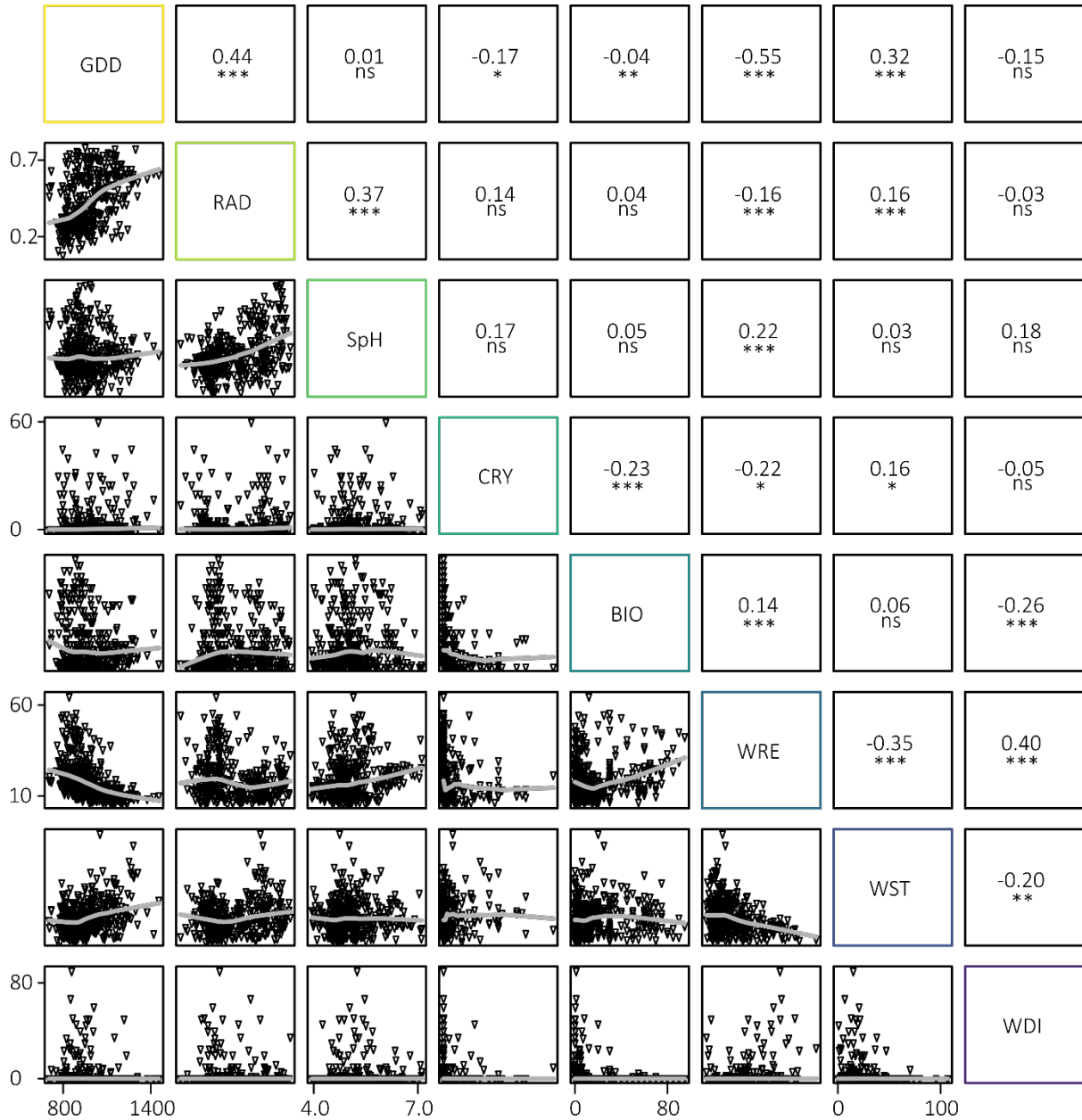
Appendix 2

Summary statistics of the predictors based on 378 observations, mean, standard deviation (Sd), and range, respectively.

Predictors	Units	Mean	Sd	Range
Growing degree day	°C	969.0	134.6	704.0 - 1455.0
Radiation	MJ/cm ² /a	0.5	0.2	0.1 - 0.9
Soil pH	pH	4.9	0.5	4.0 - 6.6
Cryogenic processes	%	3.4	8.3	0.0 - 60.0
Biota	%	18.9	22.5	0.0 - 95.0
Water resources	WVC%	19.6	11.3	5.5 - 64.9
Water stress	CV%	24.7	15.9	0.2 - 107.0
Water disturbance	%	3.4	10.6	0.0 - 90.0

Appendix 3

Spearman correlations between predictors. The lowest lines (in grey) depict the locally fitted function. Statistical significance of the correlation: *** = $p \leq 0.001$; ** = $p \leq 0.01$; * = $p \leq 0.05$; ns = $p \geq 0.05$. GDD = growing degree day; RAD = radiation; SpH = soil pH; CRY = cryogenic processes; BIO = biota; WRE = water resources; WST = water stress; WDI = water disturbance.



Appendix 4

Mean and standard error values (mean \pm SE) for predictive performance of the species distribution models as assessed by the area under curve (AUC) and true skill statistics (TSS) (based on 100 cross-validation rounds). Statistical significance tested with Wilcoxon's paired rank test. Base model excludes the three water-related variables.

	AUC				TSS			
	Base model	Full model	V	p]	Base model	Full model	V	p]
All taxa	0.733 \pm 0.010	0.754 \pm 0.010	7241.0	0.009	0.462 \pm 0.015	0.493 \pm 0.016	7011.0	0.028
Vascular plants	0.807 \pm 0.012	0.836 \pm 0.011	1649.5	0.004	0.577 \pm 0.021	0.622 \pm 0.020	1596.0	0.010
Mosses	0.687 \pm 0.019	0.727 \pm 0.019	324.0	0.061	0.392 \pm 0.027	0.434 \pm 0.031	296.0	0.198
Lichens	0.667 \pm 0.016	0.668 \pm 0.016	697.0	0.698	0.357 \pm 0.020	0.363 \pm 0.022	697.5	0.702

Appendix 5

Mean and standard error values (mean \pm SE) for predictive performance of species richness models measured with the root mean squared error (RMSE) and coefficient of determination (R^2) (100 permutations). The results from a two-tailed Wilcoxon's paired rank test are shown comparing the base model (excludes the three water variables) and the full model.

	RMSE				R^2			
	Base model	Full model	V	p	Base model	Full model	V	p
All taxa	6.479 \pm 0.049	6.128 \pm 0.048	4999.0	< 0.001	0.250 \pm 0.006	0.332 \pm 0.007	31.0	< 0.001
Vascular plants	5.168 \pm 0.037	4.507 \pm 0.037	5009.0	< 0.001	0.427 \pm 0.006	0.568 \pm 0.007	1.0	< 0.001
Mosses	2.107 \pm 0.014	1.999 \pm 0.013	4999.0	< 0.001	0.097 \pm 0.004	0.193 \pm 0.005	1.0	< 0.001
Lichens	3.885 \pm 0.026	3.714 \pm 0.025	5026.0	< 0.001	0.271 \pm 0.005	0.335 \pm 0.005	30.0	< 0.001

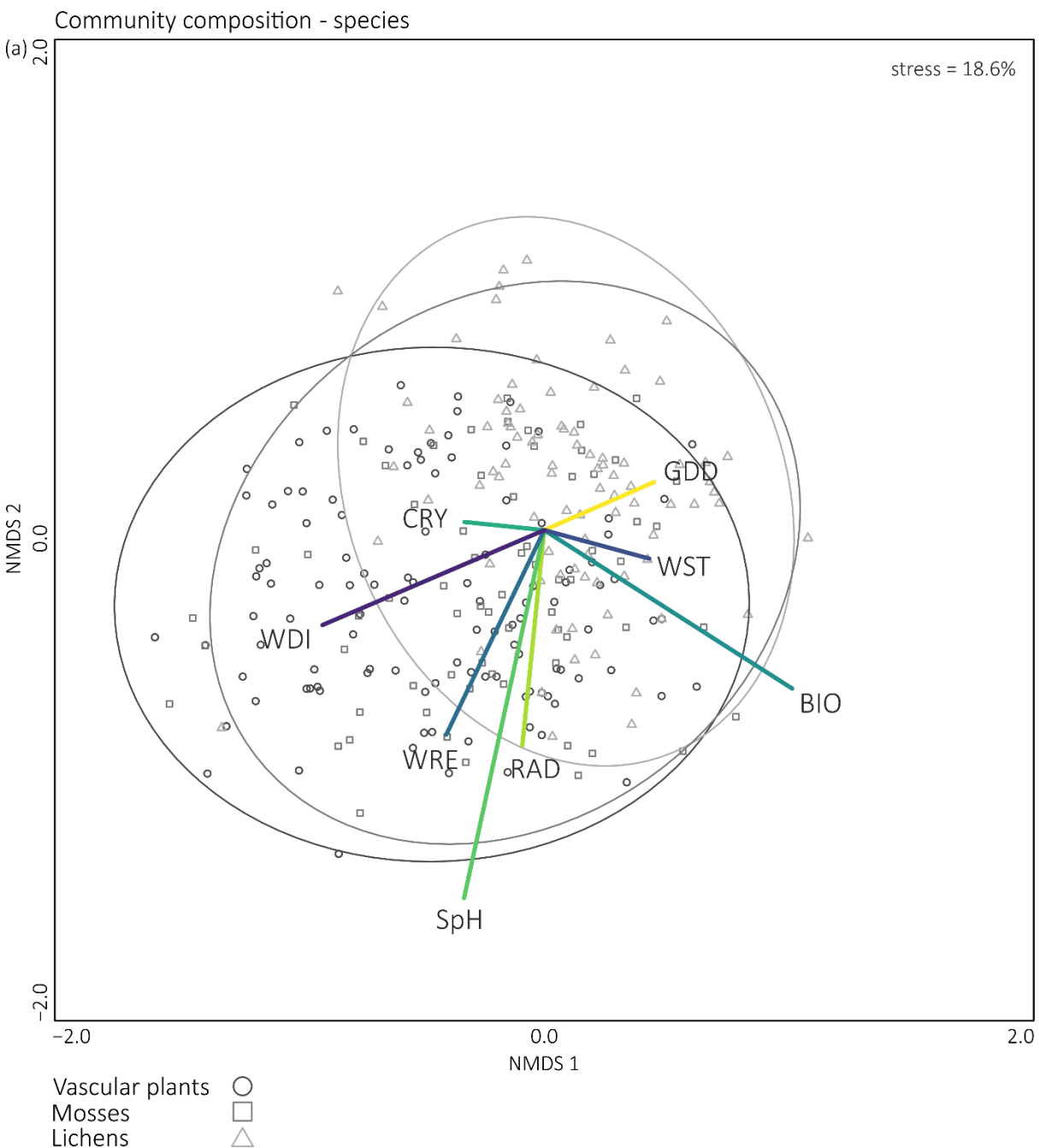
Appendix 6

The relationship between predictor variables and community composition (as qualified by NMDS scores) of whole species community models (stress = 17.0%). GDD = growing degree day; RAD = radiation; SpH = soil pH; CRY = cryogenic processes; BIO = biota; WRE = water resources; WST = water stress; WDI = water disturbance.

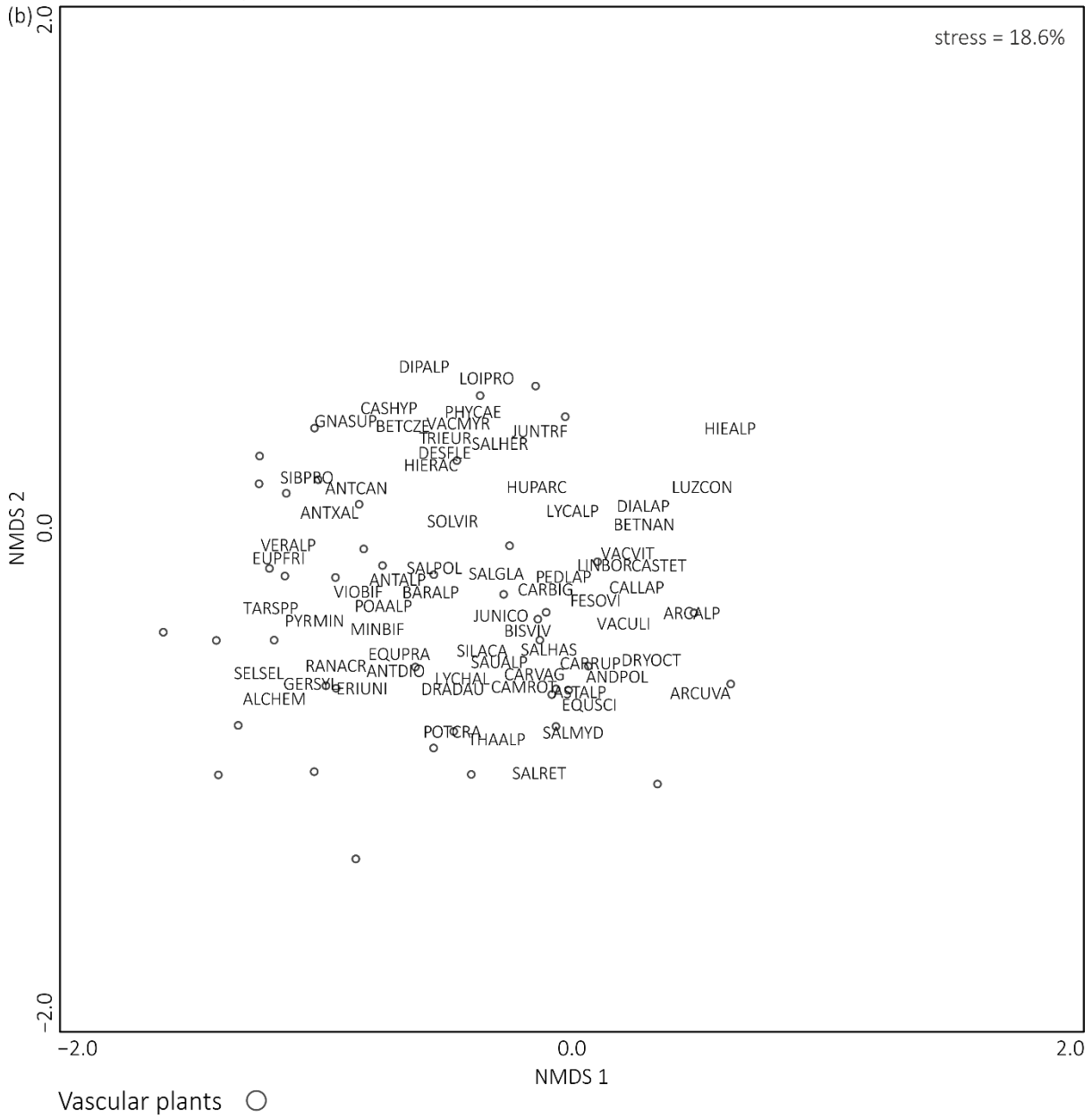
	NMDS1	NMDS2	R ²	p
GDD	0.916	0.400	0.051	0.001
RAD	-0.102	-0.995	0.167	0.001
SpH	-0.213	-0.977	0.506	0.001
CRY	-0.995	0.102	0.023	0.008
BIO	0.843	-0.538	0.310	0.001
WRE	-0.433	-0.901	0.183	0.001
WST	0.965	-0.261	0.042	0.002
WDI	-0.920	-0.393	0.208	0.001

Appendix 7

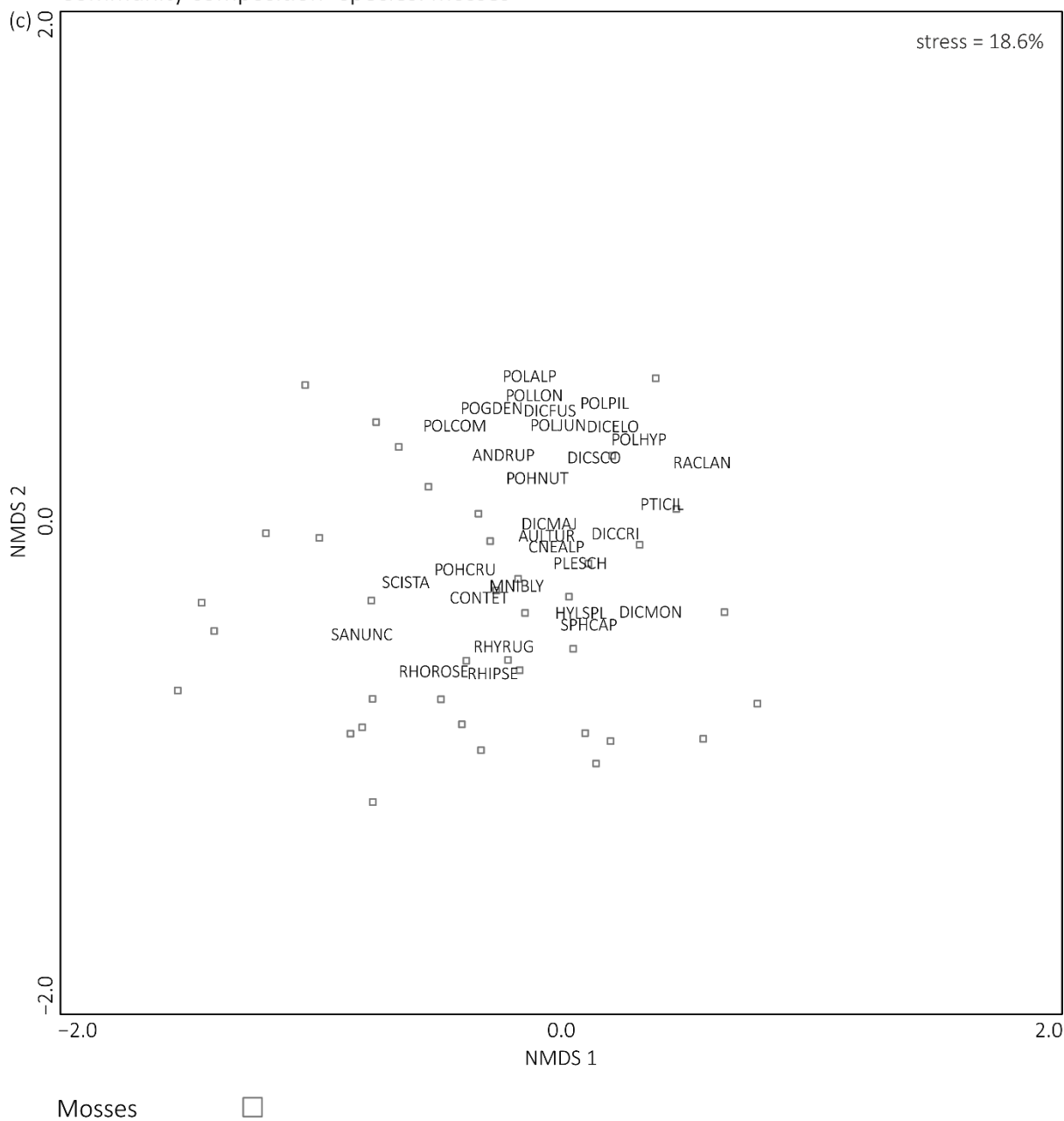
Ordination plot of community composition (a), in which individual species are plotted in grey symbols (three dimensions; stress = 18.6%). For visualization, the same information is presented by dividing the first figure (a) according to taxonomic group (b–d). Vascular plant species were separated chiefly along NMDS1 and lichens species along NMDS2, with an intermediate pattern observed for mosses. Abbreviations for species name provided in Appendix 1. Only species present in ≥ 8 of the plots are indicated. Overlapping labels were slightly moved for readability. The ellipsoids represent the 95% confidence interval, with vascular plant species in dark grey, mosses in grey, and lichens in light grey (a). Vascular plant species are indicated with dark grey circles (a, b), mosses with grey squares (a, c), and lichens with light grey triangles (a, d). GDD = growing degree day; RAD = radiation; SpH = soil pH; CRY = cryogenic processes; BIO = biota; WRE = water resources; WST = water stress; WDI = water disturbance.



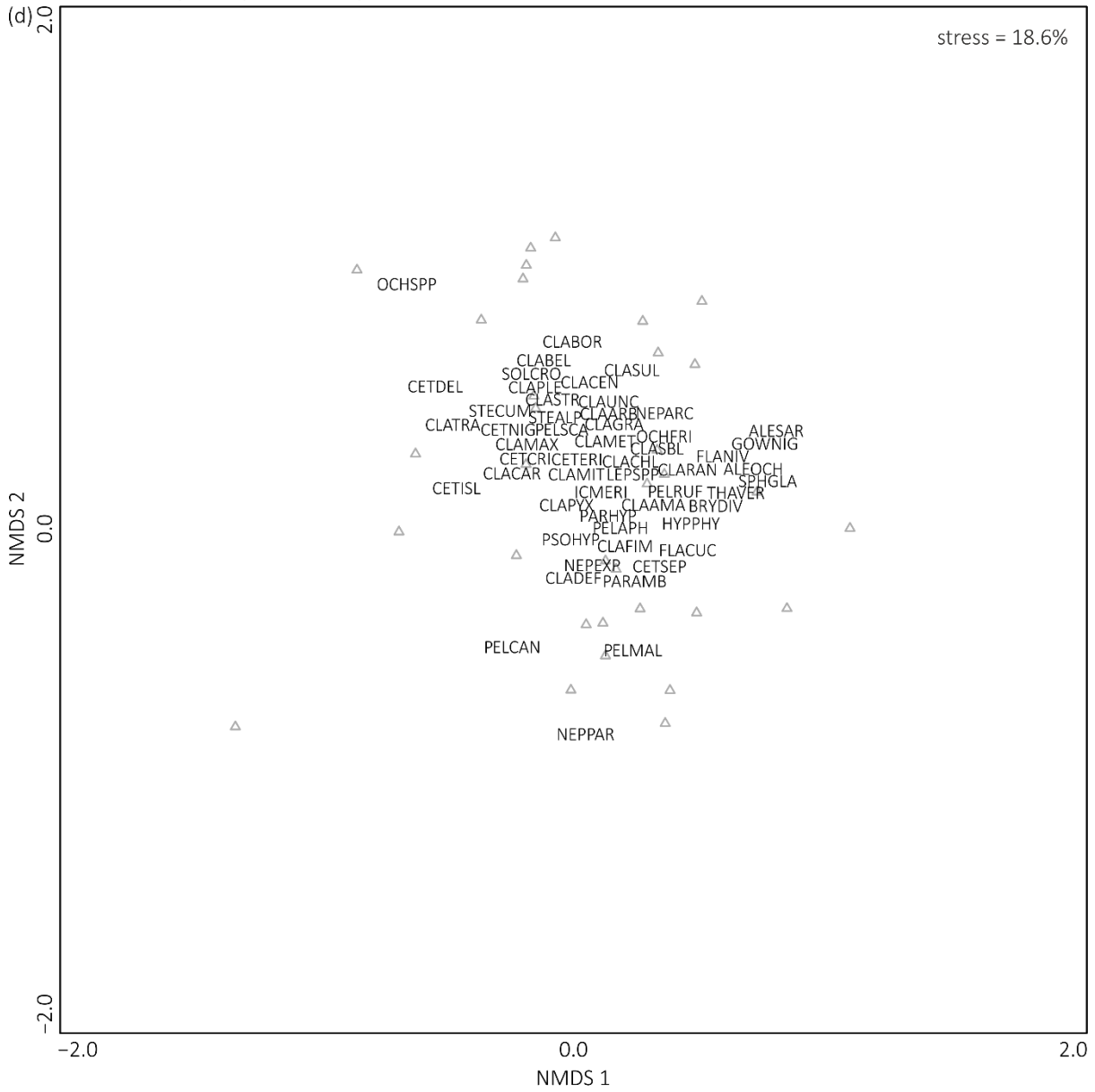
Community composition- species: vascular plants



Community composition- species: mosses

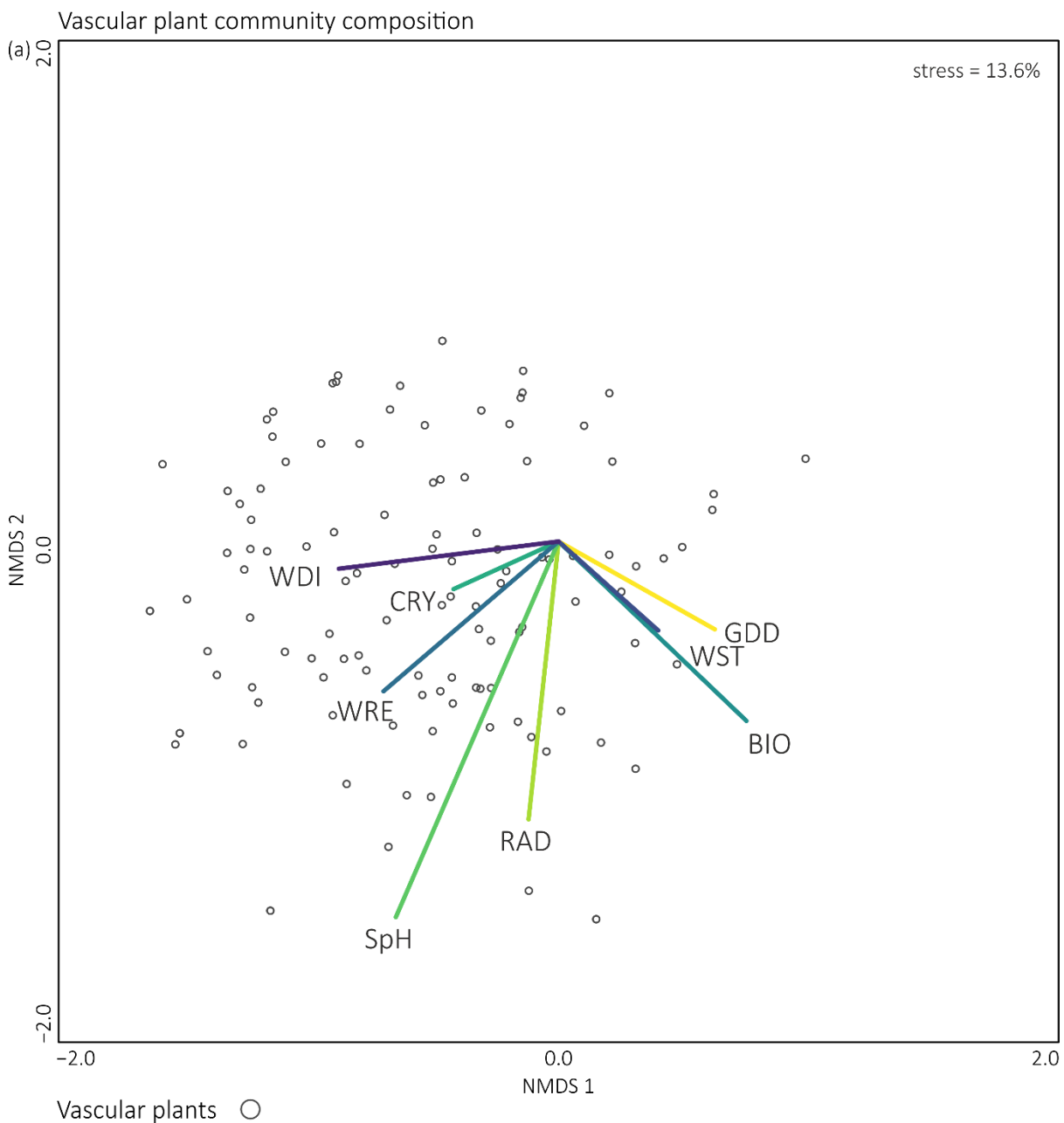


Community composition- species: lichens

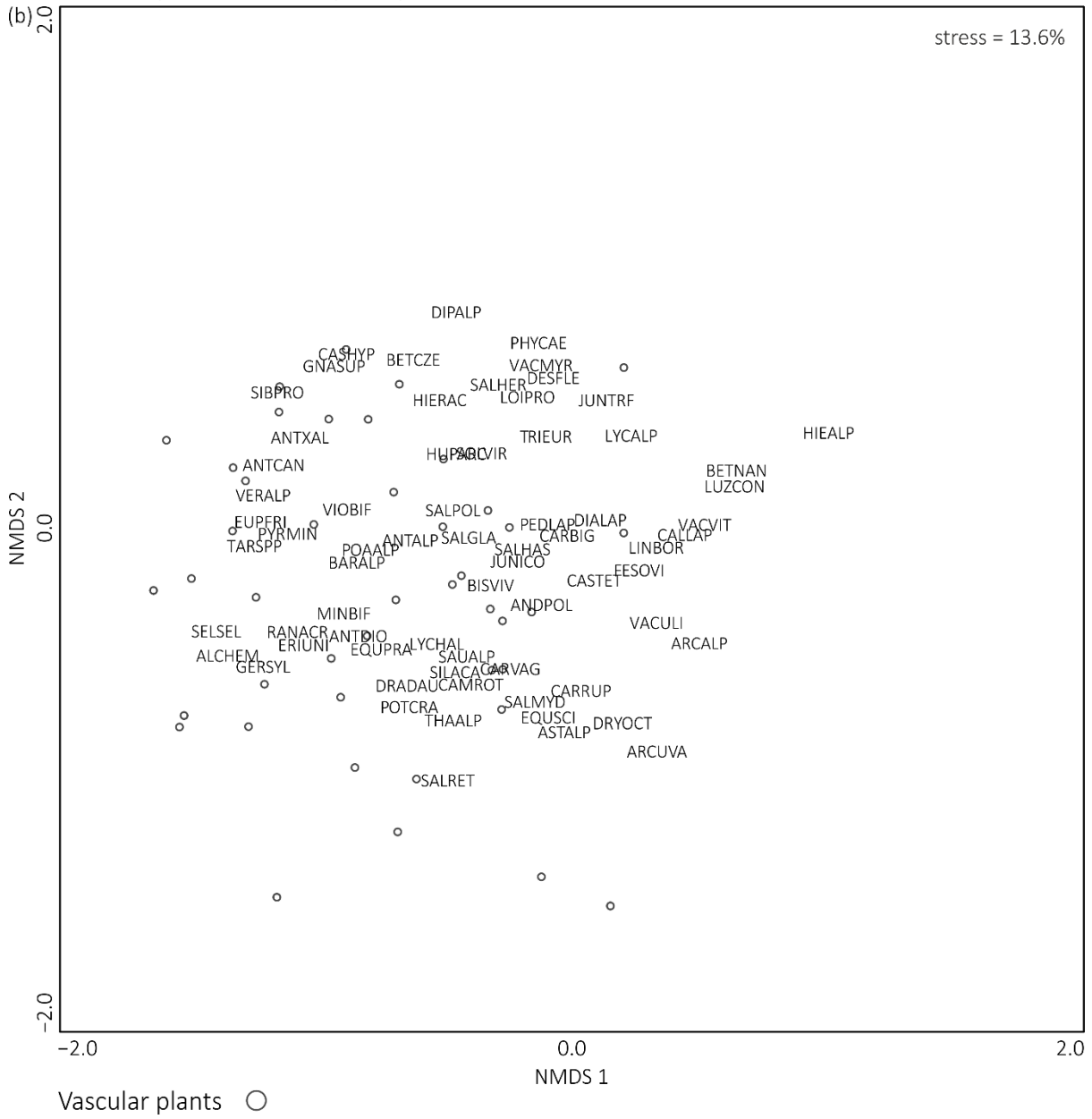


Appendix 8

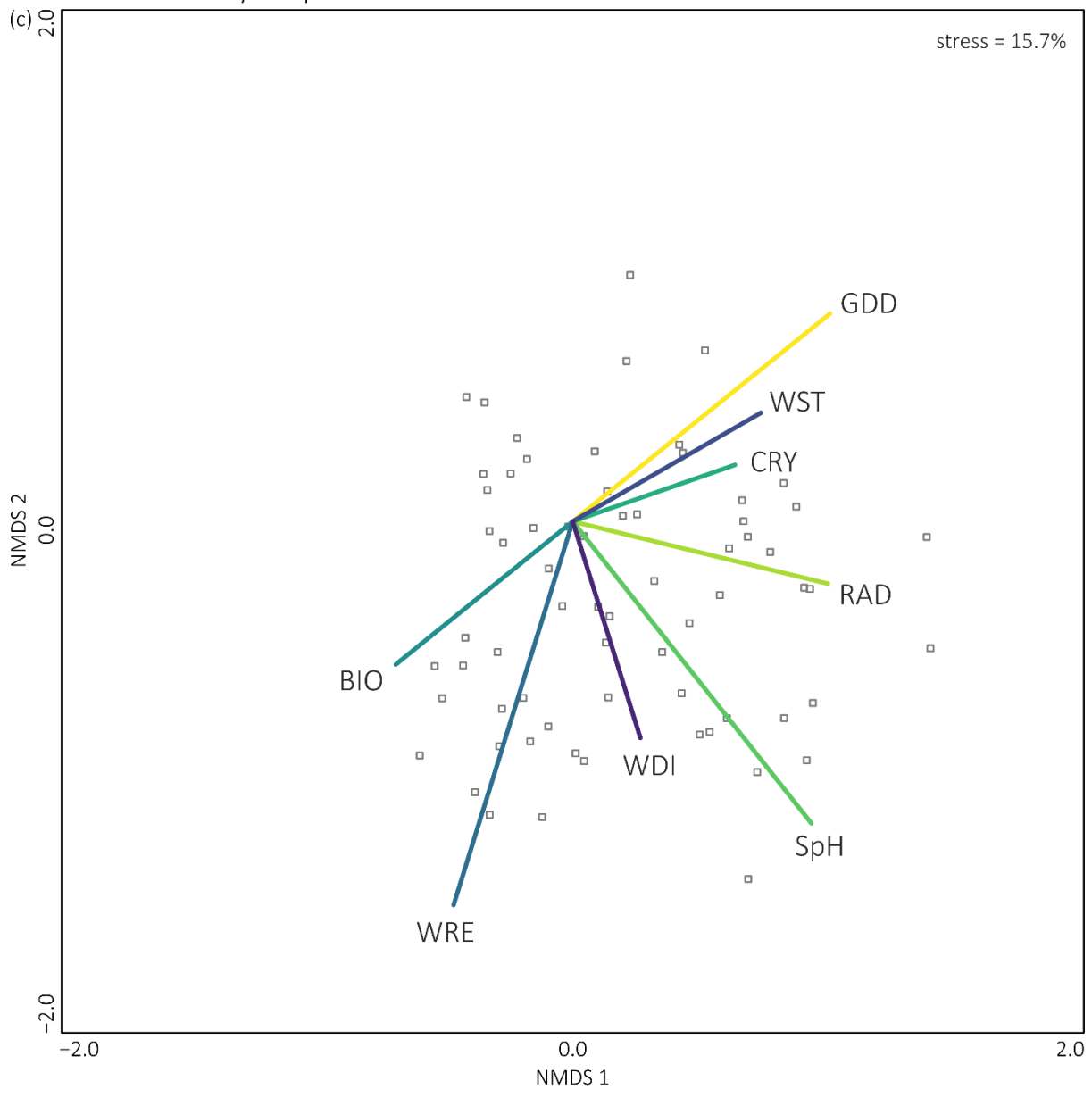
Ordination plots of vascular plant, moss, and lichen community composition (a, c, e). In contrast to the ordinations in Appendix 7, here NMDS was used to perform ordination for each taxonomic group separately, highlighting the relative influence of predictor variables separately for each taxonomic group. Individual species are plotted in grey symbols. Abbreviations for species name provided in Appendix 1. Only species present in ≥ 8 of the plots are indicated. Overlapping labels were slightly moved for readability. Vascular plant species are indicated with dark grey circles (a, b), mosses with grey squares (c, d), and lichens with light grey triangles (e, f). GDD = growing degree day; RAD = radiation; SpH = soil pH; CRY = cryogenic processes; BIO = biota; WRE = water resources; WST = water stress; WDI = water disturbance.



Vascular plant community composition

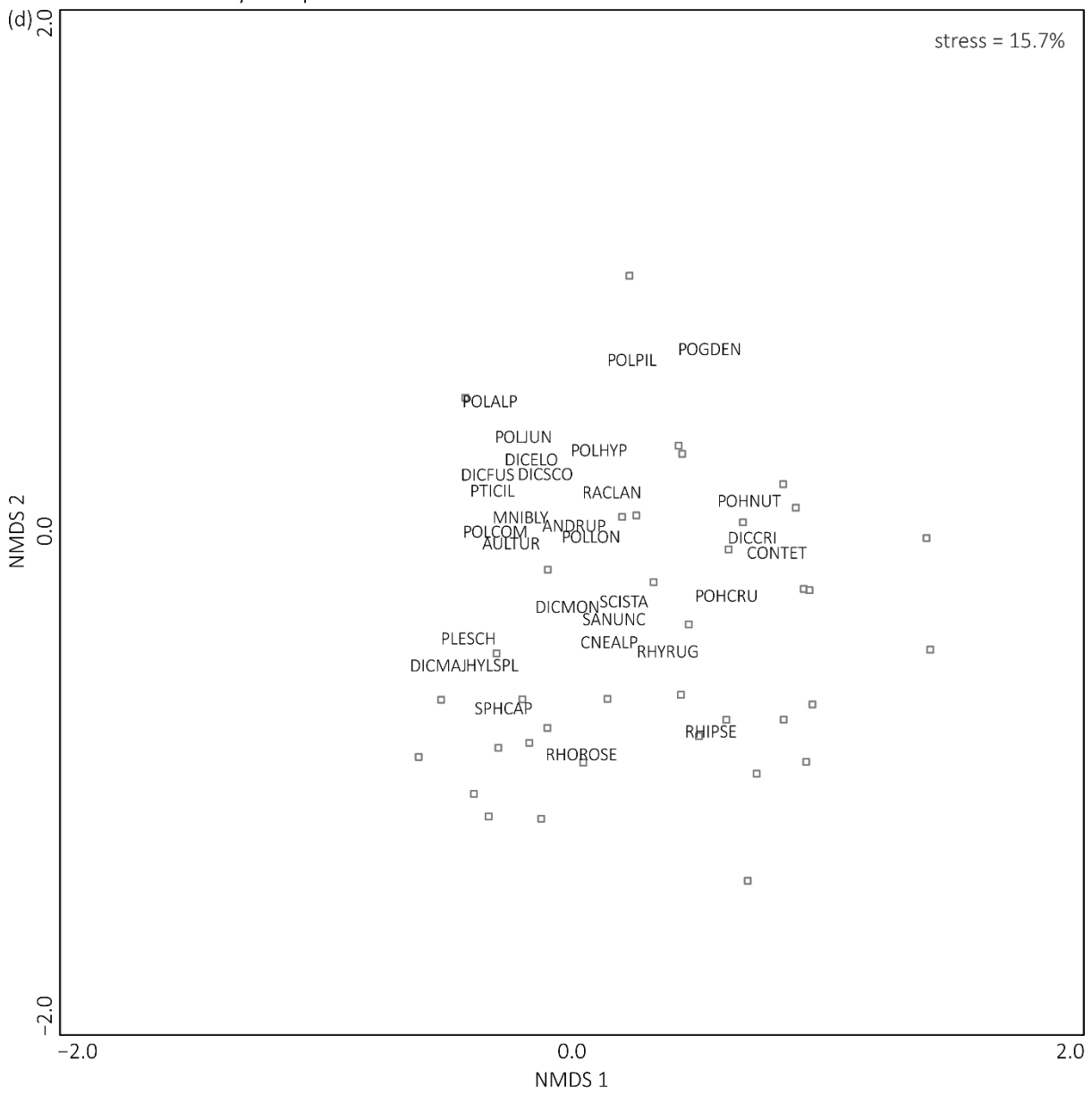


Moss community composition

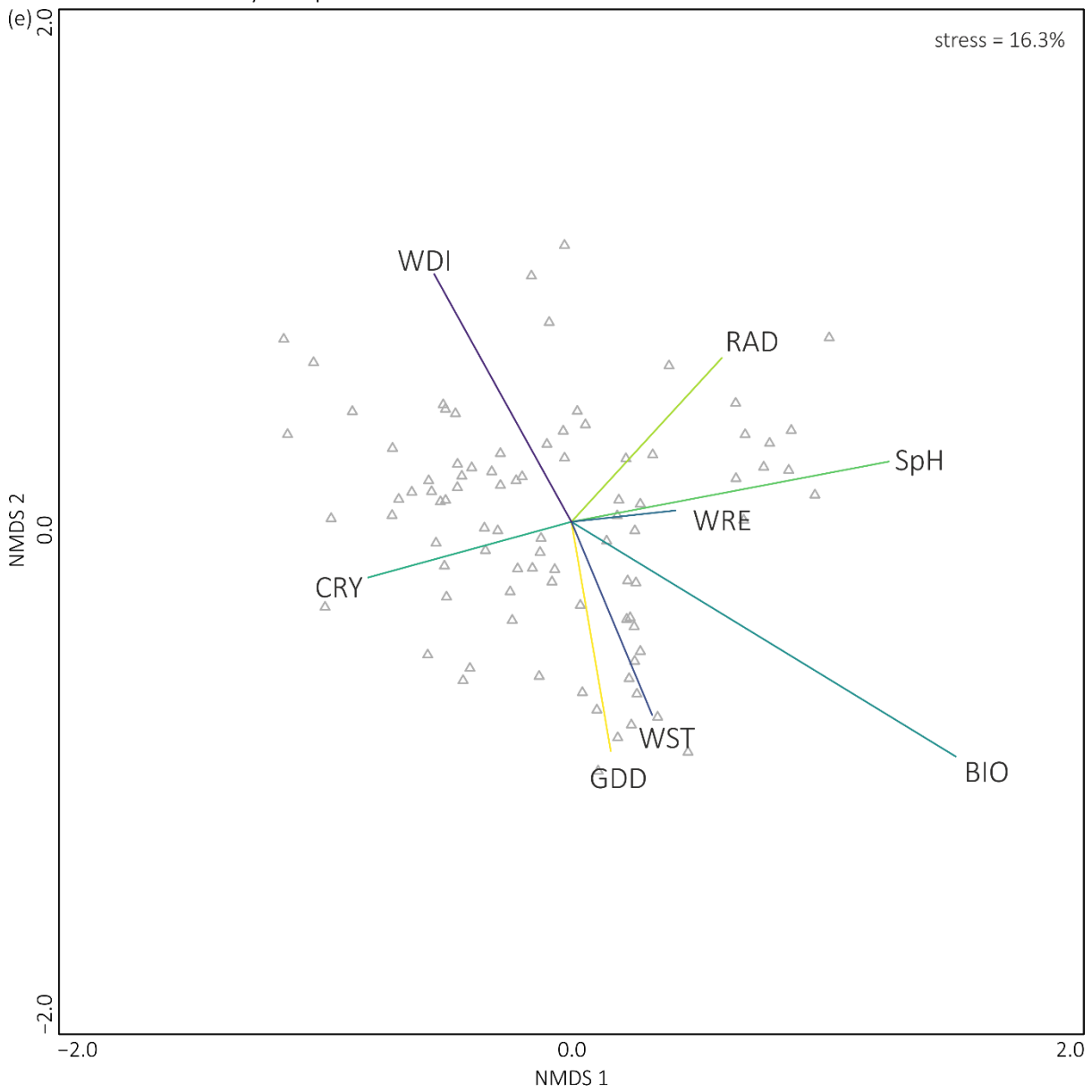


Mosses □

Moss community composition



Lichen community composition



Lichens △

Lichen community composition

