Ecography

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Supplementary material

Table S1. Environmental predictors used to fit species distribution models of six snowbed plants of the northeastern calcareous Alps, the sources they were derived from, and their importance in the four different statistical model types applied (GLM – generalized linear model, GAM – generalized additive model, GBM – boosted regression tree model; RF – random forest model). For GLM and GAM, values represent the increase in residual deviance when dropping the respective predictor from the model; no values are given for predictors that have not been selected by the stepwise algorithm (function *step* in R, R Development Core Team 2008). For GBM and RF, values represent the relative importance of predictors in terms of reducing the loss function, i.e. the squared errors (GBM), or the accuracy of the regression trees (RF), cf. Liaw and Wiener (2002) and Ridgeway (2007). See methods for more details on how the four models were fitted. An in-depth description of how the individual predictors were calculated is given in Dirnböck et al. (2003).

		Achillea clusiana				*Achillea atrata*				*Arabis caerulea*			
Variable	Source data	GLM	GAM	GBM	RF	GLM	GAM	GBM	RF	GLM	GAM	GBM	RF
Altitude	DEM[1]	16.81	9.89	16.93	0.98	16.52	–	12.40	1.05	–	–	20.32	0.89
Slope Inclination	DEM	–	9.30	4.93	0.82	–	8.11	7.71	0.83	–	–	3.86	0.51
Degree Days[2]	DEM, climate station data	14.51	7.33	12.79	0.99	28.44	24.7	8.66	1.07	27.74	38.44	16.08	0.94
SRI_May[3]	DEM, Solarflux	17.37	–	6.12	0.79	–	–	4.97	0.82	–	7.00	3.09	0.62
SRI_July[3]	DEM, Solarflux	13.66	–	2.60	0.79	–	6.04	4.24	0.90	–	–	2.70	0.57
SRI_September[3]	DEM, Solarflux	–	16.26	10.25	0.81	–	8.11	6.82	0.79	–	7.00	2.70	0.57
Water Balance August[4]	DEM, Solarflux, Climate station data	16.33	12.09	18.73	1.05	–	10.49	10.10	1.13	8.00	–	11.07	0.87
Wetness Index[5]	DEM, TAPES-G	11.82	6.54	5.79	0.55	9.39	6.66	11.48	0.69	–	–	10.62	0.59
Erosion Index[6]	DEM, TAPES-G	–	10.13	8.53	0.32	–	–	9.39	0.57	8.28	16.58	15.38	0.54
Wind speed[7]	DEM, NUATMOS	–	–	7.97	0.56	20.07	–	13.41	0.82	–	–	7.96	0.31
Snow Cover Probability[8]	DEM, SOALRFLUX, TAPES-G, NUATMOS, SPOT scenes	–	–	1.65	0.63	–	7.67	2.73	0.59	14.22	22.50	2.34	0.46
Geological substrate[9]	Geological map	–	–	2.82	0.32	27.80	–	4.90	0.38	–	–	2.44	0.46
Land use[10]	Historical documents	–	2.31	0.90	0	8.48	10.33	3.17	0.65	–	11.43	1.44	0.16

	Gnaphalium hoppeanum				*Saxifraga stellaris*				*Sedum atratum*			
Variable	GLM	GAM	GBM	RF	GLM	GAM	GBM	RF	GLM	GAM	GBM	RF
Altitude	4.55	7.34	18.52	0.96	4.12	–	12.12	1.02	–	–	9.50	0.89
Slope Inclination	–	–	8.57	0.80	–	–	7.13	0.91	17.92	14.47	6.79	0.99
Degree Days	6.73	10.93	12.96	1.03	13.04	73.26	16.33	1.02	15.10	16.45	8.68	0.91
SRI_May	4.96	–	4.89	0.74	9.94	–	4.36	0.91	–	–	7.20	0.94
SRI_July	5.11	–	4.97	0.76	9.50	–	4.42	0.86	–	–	5.20	0.95
SRI_September	11.81	6.23	3.32	0.69	10.80	18.5	8.39	0.89	–	–	11.55	0.92
Water Balance August	8.51	11.62	11.36	0.97	–	–	16.03	1.07	5.46	–	7.94	0.83
Wetness Index	–	–	6.29	0.74	–	–	5.79	0.64	–	–	6.92	0.66
Erosion Index	–	–	10.28	0.46	4.40	11.46	10.72	0.34	–	–	15.07	0.66
Wind speed	10.32	–	10.17	0.56	–	–	9.61	0.71	–	–	11.69	0.66
Snow Cover Probability	–	12.36	2.62	0.64	–	–	1.44	0.46	6.20	6.16	2.74	0.64
Geological substrate	–	–	2.44	0.33	–	–	1.47	0.42	–		4.72	0.72
Land use	–	–	3.62	0.33	–	–	2.17	0.24	4.27	5.04	2.01	0.38

[1] Derived from a digital elevation model (resolution: 20 × 20 m), provided by the Austrian Mapping Agency (Österreichisches Bundsamt für Eich- und Vermessungswesen).
[2] Number of days with a daily mean temperature > 0°C; calculated as a function of altitude and geographical latitude using half-hourly measurements during the years 1995–1999 from a total of 20 climate stations in the northeastern Calcareous Alps of Austria.
[3] Daily net radiation for 15 May, 15 July and 15 September, derived by applying SOLARFLUX (Rich et al. 1995) under clear sky conditions with the DEM. The program accounts for relief shading and topographic position. For the whole area, atmospheric transmissivity was set to 0.8. Radiation was calculated at hourly intervals which were then summed for the whole day.
[4] Precipitation less potential evapotranspiration (Turc 1961), averaged for 1 and 15 August, and 1 September. As input parameters to the formula of Turc (1961), daily net radiation was calculated applying SOLARFLUX under the same settings as described above; temperature and precipitation were calculated by regressing measurements from the above mentioned 20 stations against altitude and geographical latitude.
[5] Spatial distribution of zones of saturation as well as runoff generation, calculated from the DEM using the software TAPES-G (Gallant and Wilson 1996).
[6] Spatial distribution of soil loss, erosion and deposition potential, calculated from the DEM using the software TAPES-G (Gallant and Wilson 1996).
[7] Topographical modification of near-surface wind velocity, calculated with the diagnostic wind field model NUATMOS (Version 5N, 07/31/91; Ross et al. 1988, integrated in a GIS by Bachmann 1998).
[8] Probability of snow cover, calculated by relating snow melt date as derived from a series of 11 SPOT scenes (acquired 1998, 1999, 2000 from February to June) to altitude, slope, cumulative solar radiation income (from 1 January until the date when the last spot scene was acquired, calculated by means of SOLARFLUX), topographically modified wind velocity (calculated by NUATMOS), wetness and erosion indices and plant cover type (krummholz versus grasslands, screes and rocks, derived from a vegetation map). The relationship was established by means of a classification tree, and the measure derived was the mean probability of a cell to be covered by snow across all days from which SPOT scenes were available.
[9] Derived from a detailed geological map (Geological Survey of Austria, unpublished), categorised into 9 geological units (limestone, dolomite, clayey weathering carbonates, relict loam, carbonate debris###).
[10] Time of pasture abandonment – from catastral maps and a suite of documents referring to the land use status of individual parcels at different times (Dullinger et al. 2003). To achieve uniform precision of the land use data for the whole study area we categorised time since abandonment using the six main historical documents as reference points and assigning each parcel (= all cells within this parcel, excluding rock faces and scree areas) the date of its last documented use as a pasture. In statistical analyses we used the number of years between the dates of documented pasture uses and the year 2000. Areas which have never been used were assigned a value of 1000 assuming this period to be sufficient to completely eliminate all remnants of former pasturing.

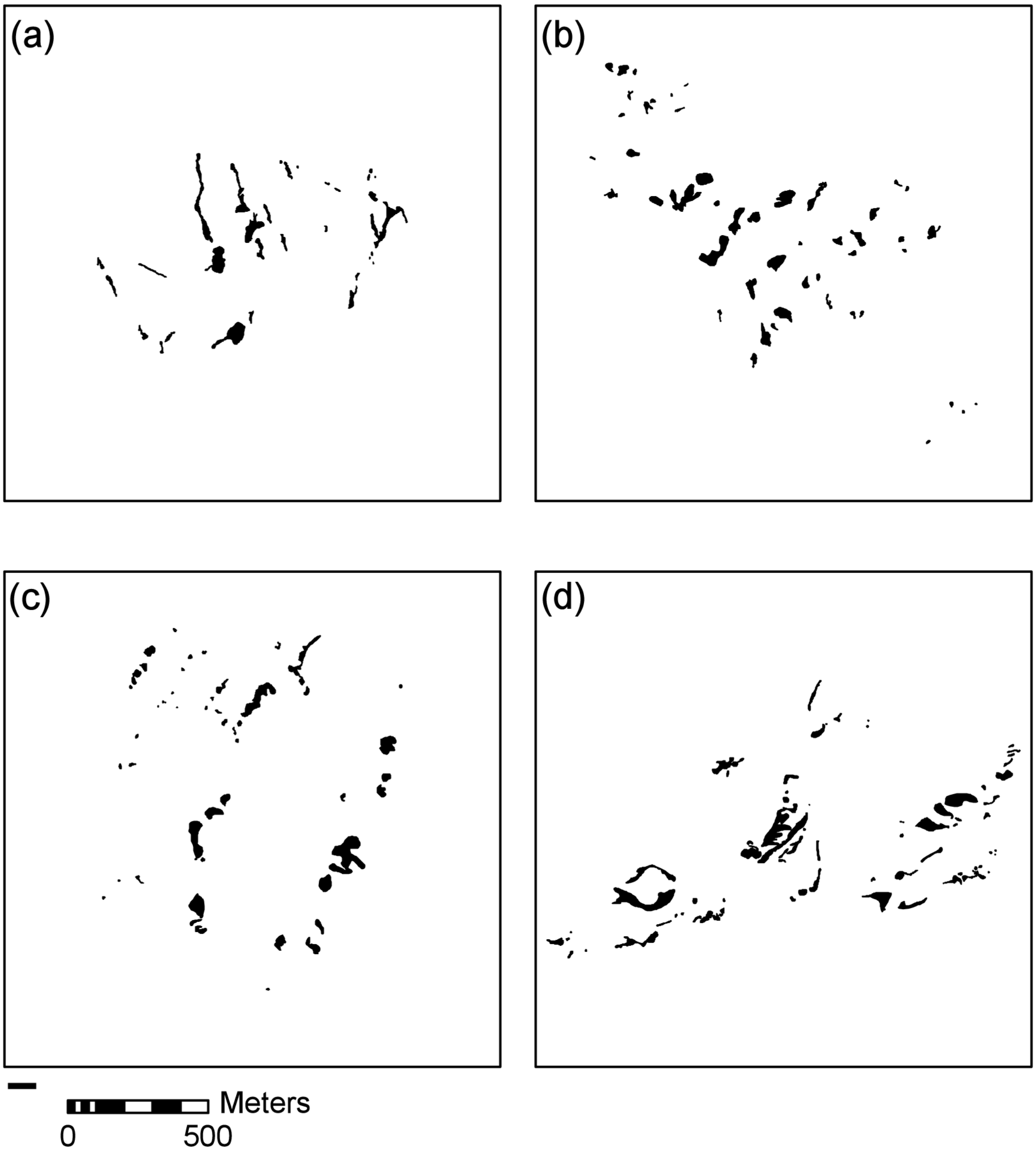

Figure S1. Distribution of snowbed patches in four study sites at four mountain ranges of the northeastern Calcareous Alps, Austria. (a) Mt. Schneeberg, (b) Mt. Schneealpe, (c) Mt. Rax, (d) Mt. Hochschwab.

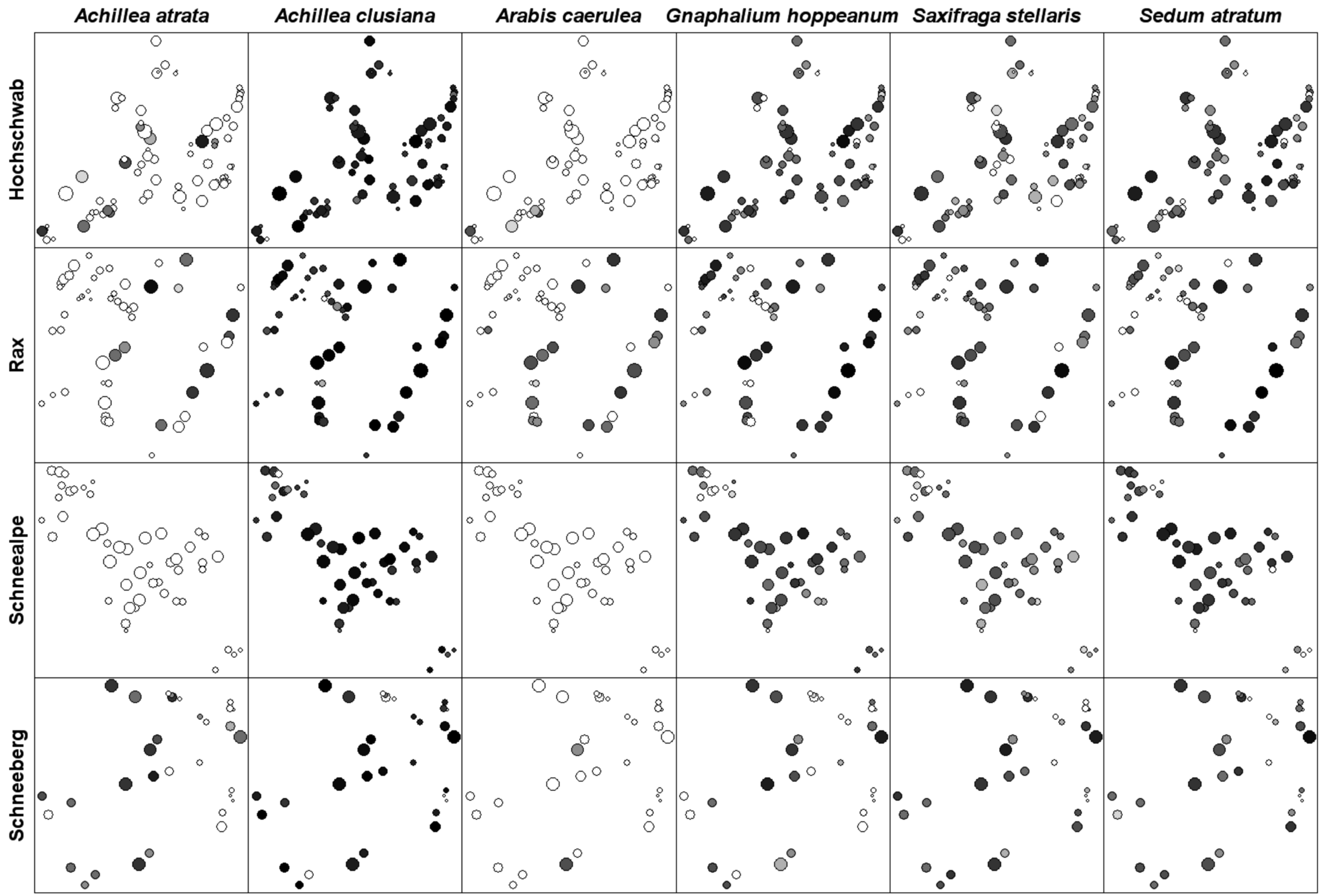

Figure S2. Schematic representation of the distribution and abundance of six plant species across 212 snowbed patches in four different study areas of the northeastern Calcareous Alps, Austria. Dot sizes scale patch area, and the grey shades symbolize the species' abundance according to a log-scaled recording scheme from absent (white) to > 10 000 (black) individuals or rosettes, respectively.

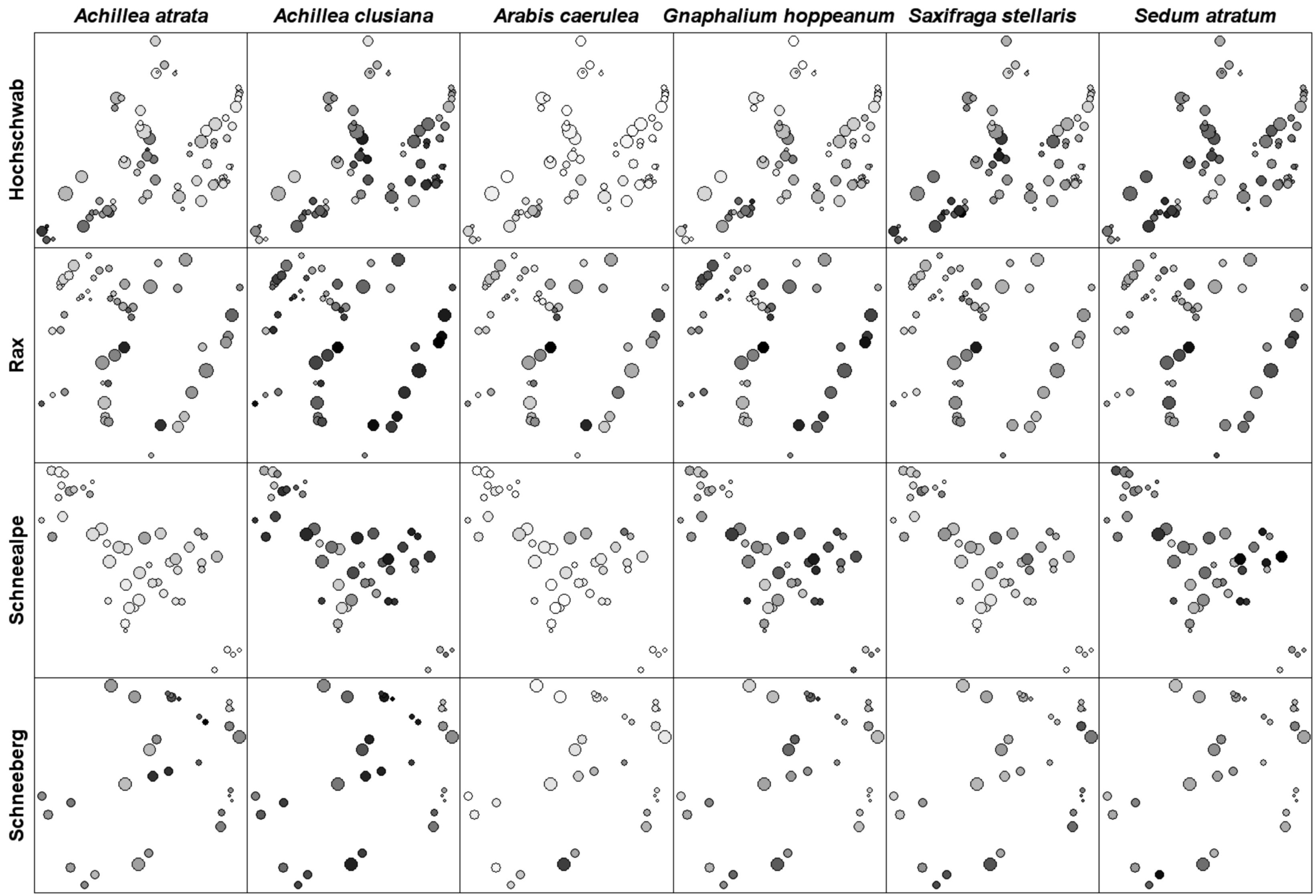

Figure S3. Schematic representation of the habitat suitability that niche-based distribution models of six plant species predicted across 212 snowbed patches within four different study areas of the northeastern Calcareous Alps, Austria. Dot sizes scale patch area, and the dot shades symbolize predicted occurrence probabilities of the individual species in the respective patches. Shades were adapted to the overall range of predicted probabilities per species with white representing lowest and black highest values.

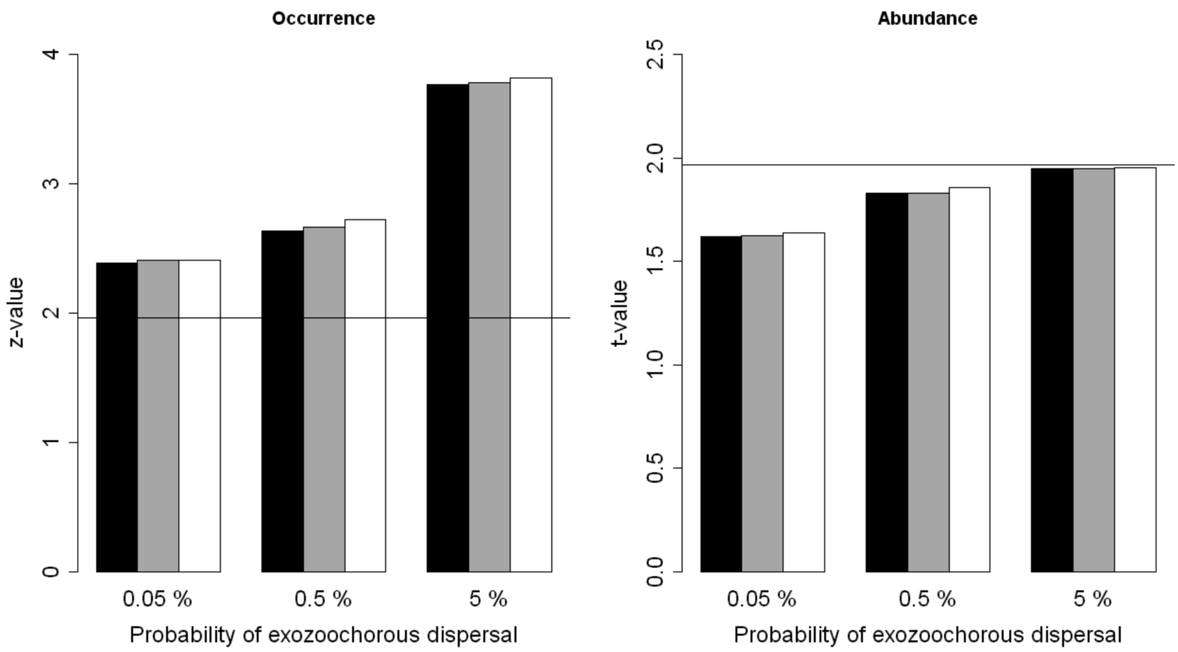

Figure S4. Test statistic-values of the fixed-effects coefficient of the SEEDS variable in a generalized linear mixed model of occurrence, or a linear mixed model of abundance of six plant species across 212 patches in four different study areas of the northeastern Calcareous Alps of Austria as a function of how seed yield is partitioned among wind, endo- and epizoochorous dispersal kernels. SEEDS is the number of seeds a patch is simulated to receive from all other patches in the system according to these three dispersal kernels and their mixture ratio. The different grey shades indicate the share of the endozoochorous component (dark grey: 0.05%, medium grey: 0.5%, light grey: 5%). The dashed lines represent the 5%-significance threshold of the standard normal variable *z* (~ 1.96) or the test-statisic *t* (~ 1.97 for 390 degrees of freedom).

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