

Journal of Biogeography
SUPPORTING INFORMATION

The rich sides of mountain summits - a pan-European view on aspect preferences of alpine plants

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Appendix S2 – S7

Appendix S2 Comparison of aspect differences in temperature sums across temperature thresholds (1-5 °C) and growing season lengths (June to August vs. May to September). Given are p-values of fixed effects of linear mixed-effects models comparing temperature sums among cardinal directions on European mountain summits in the Mediterranean (a), temperate (b) and boreal (c) biomes. To allow for comparisons between each pairwise combination of cardinal directions we re-fitted the models with different cardinal directions as baseline level, which is given first in the table. P-values below 0.05 and 0.1 are given in bold and are underlined, respectively.

Temperature sums		Pr(> z)					
threshold [°C]	Vegetation period	East-South	East-West	East-North	South-West	South-North	West-North
(a) Mediterranean							
1	May-Sep	0.879	<u>0.053</u>	0.006	0.033	0.003	0.378
1	Jun-Aug	0.737	0.048	0.007	<u>0.083</u>	0.012	0.427
2	May-Sep	0.926	0.048	0.005	0.033	0.003	0.363
2	Jun-Aug	0.729	0.046	0.006	<u>0.081</u>	0.012	0.420
3	May-Sep	0.979	0.043	0.004	0.034	0.003	0.352
3	Jun-Aug	0.718	0.044	0.006	<u>0.079</u>	0.011	0.414
4	May-Sep	0.965	0.039	0.004	0.036	0.003	0.347
4	Jun-Aug	0.702	0.041	0.005	<u>0.078</u>	0.011	0.411
5	May-Sep	0.917	0.034	0.003	0.036	0.003	0.353
5	Jun-Aug	0.685	0.038	0.005	<u>0.076</u>	0.010	0.411
(b) Temperate							
1	May-Sep	0.435	0.012	0.000	0.001	0.000	0.002
1	Jun-Aug	0.811	0.004	0.000	0.009	0.000	0.025
2	May-Sep	0.456	0.007	0.000	0.001	0.000	0.003
2	Jun-Aug	0.827	0.003	0.000	0.006	0.000	0.036
3	May-Sep	0.479	0.005	0.000	0.001	0.000	0.007
3	Jun-Aug	0.847	0.002	0.000	0.004	0.000	<u>0.053</u>
4	May-Sep	0.503	0.003	0.000	0.000	0.000	0.012
4	Jun-Aug	0.867	0.002	0.000	0.003	0.000	<u>0.075</u>

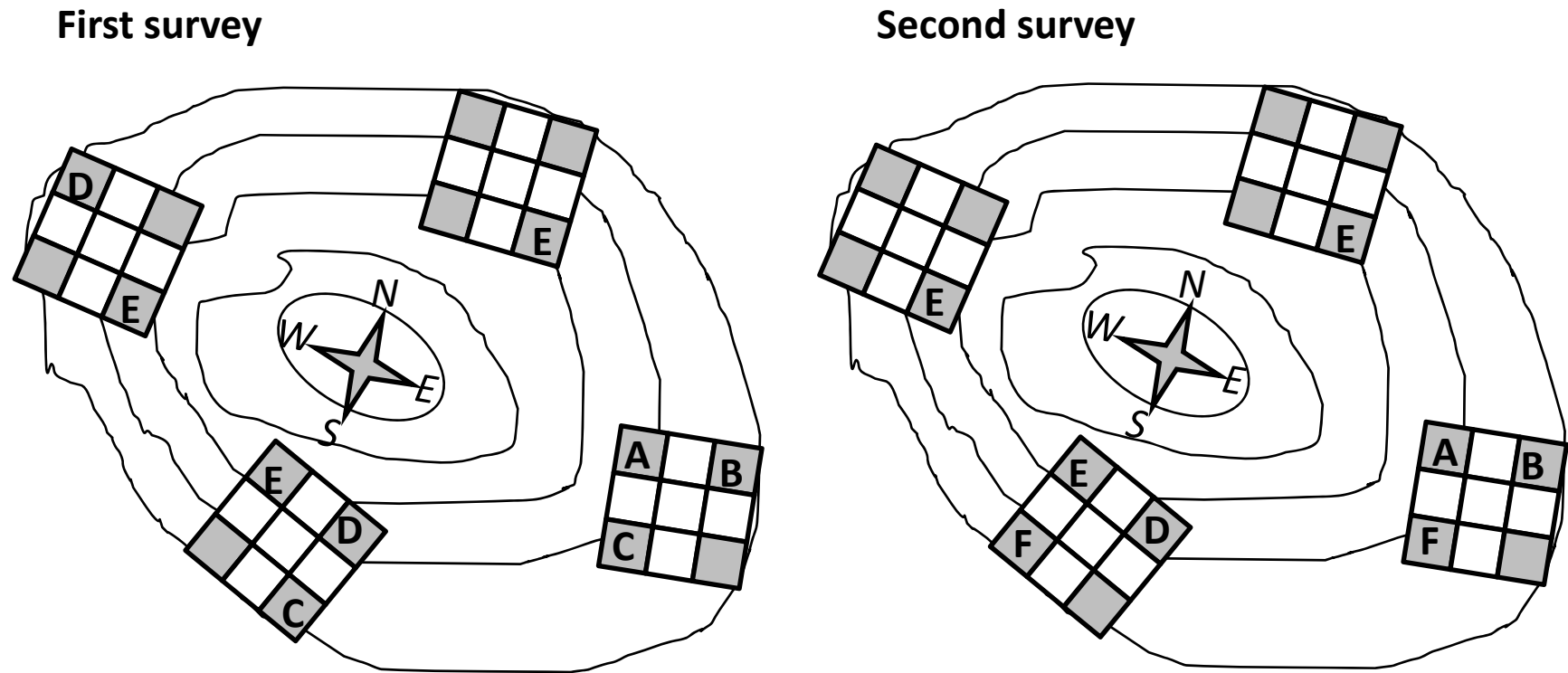
5	May-Sep	0.526	0.003	0.000	0.000	0.000	0.021
5	Jun-Aug	0.887	0.002	0.000	0.003	0.000	0.101
(c) Boreal							
1	May-Sep	0.920	0.335	0.013	0.294	0.011	0.108
1	Jun-Aug	0.924	0.369	0.025	0.327	0.021	0.159
2	May-Sep	0.913	0.320	0.013	0.276	0.010	0.115
2	Jun-Aug	0.918	0.361	0.025	0.317	0.021	0.163
3	May-Sep	0.904	0.309	0.013	0.263	0.010	0.122
3	Jun-Aug	0.913	0.355	0.024	0.309	0.020	0.166
4	May-Sep	0.893	0.303	0.014	0.251	0.011	0.130
4	Jun-Aug	0.905	0.348	0.024	0.297	0.019	0.166
5	May-Sep	0.875	0.302	0.014	0.241	0.010	0.133
5	Jun-Aug	0.889	0.340	0.022	0.281	0.017	0.161

Appendix S3 Number of gaps in soil temperature measurement series on 67 European mountain summits in 17 regions (cf. Fig. 1, Appendix S1). Complete datasets per temperature logger encompass 22032 hourly measurements from May 1 to September 30 of the years 2002 to 2007. Data series with up to 9004 missing measurements were completed through imputation. Data series with larger gaps, printed in bold, were excluded from the data analysis (18 loggers out of a total of 268).

Region	Summit altitude	Number of gaps			
		East	South	West	North
3	742	4	2659	3	3
3	904	4	6	2181	10311
3	978	10623	0	3280	2
3	1111	2	6	0	7743
4	1161	2921	26	30	27
4	1418	32	25	29	25
4	1651	21	21	22	2958
4	1845	8115	2936	2936	2938
6	492	37	24	30	28
6	1000	29	54	30	8
6	1300	21	9004	21	23
6	1560	8972	8969	8959	8962
8	1109	75	74	9891	13954
8	1413	28	29	2988	27
8	1437	3237	3019	27	27
8	1565	26	10844	3011	24
9	300	26	19	2602	17
9	417	45	34	36	34
9	641	27	2588	26	31
9	839	30	19253	31	29
11	2242	22	8094	21	19
11	2519	23	27	10943	23
11	2779	33	19034	52	41
11	3022	27	11545	67	55
13	2360	6	7	2919	2919
13	2550	2	2926	5	7
13	2989	8	10	8	8
13	3212	7	8	8	11
17	1722	59	29	26	33
17	1815	24	22	27	24
17	1855	27	25	30	25
17	1978	3708	3775	61	3722
19	2199	2736	28	5071	949

19	2463	2863	28	2873	30
19	2757	5749	57	2983	56
19	2893	3060	65	2999	40
22	1910	3113	0	15	13
22	2065	9	8	8	7356
22	2214	27	21	25	24
22	2255	2592	3110	3112	3110
23	1919	12	12	12	11
23	2052	15	14	3687	15
23	2061	16	25	18	24
23	2336	18	17	3652	3649
24	2063	17	2495	2497	2518
24	2116	2496	2499	2498	18
24	2221	2497	2518	2234	2517
24	2268	5790	2501	78	2499
25	2240	2415	10383	5	56
25	2477	9883	1866	7376	11016
25	2815	0	4607	2330	2387
25	3024	2389	2389	8	0
27	2778	4	4	4	5
27	2968	5	5	7	7
27	3150	5	6	5	4
27	3327	6	6	6	7
30	2144	18756	NA	NA	7346
30	2305	22	12	NA	18807
30	2607	10804	6	10	6
31	2405	32	6	19	32
31	2511	19826	7518	10233	19826
31	2635	24	21	11	19
31	2737	22	21	22	23
32	1664	11	10	10	7094
32	1965	20	24	26	24
32	2160	9	10	6	10
32	2339	24	24	25	22

Appendix S4 Example for species pool definition and input dataset construction for binomial generalised linear mixed-effect models used to assess the effect of cardinal direction on species richness (a), colonization (b), and disappearance of resident species (c). Capital letters in 3m x 3m grids denote exemplary species.



Species pools

(a) Species richness: all species found on a given summit during the first survey as second survey data are available only for a subset of regions: A, B, C, D, E

(b) Colonization: all species found on a summit in at least one of the observation years, minus the species already present in the respective 3m x 3m grid in the first survey:

East: D, E, F
South: A, B, F
West: A, B, C, F
North: A, B, C, D, F

(c) Disappearance: all species found in the respective 3m x 3m grid in the first survey:

East: A, B, C
South: C, D, E
West: D, E
North: E

Input datasets for GLMMs

(a) Species Richness

East	A	1
East	B	1
East	C	1
East	D	0
East	E	0
South	A	0
South	B	0
South	C	1
South	D	1
South	E	1
West	A	0
West	B	0
West	C	0
West	D	1
West	E	1
North	A	0
North	B	0
North	C	0
North	D	0
North	E	1

(b) Colonization

East	D	0
East	E	0
East	F	1
South	A	0
South	B	0
South	F	1
West	A	0
West	B	0
West	C	0
West	F	0
North	A	0
North	B	0
North	C	0
North	D	0
North	F	0

(c) Disappearance

East	A	0
East	B	0
East	C	1
South	C	1
South	D	0
South	E	0
West	D	1
West	E	0
North	E	0

Appendix S5 Fixed effects of linear mixed-effects models comparing soil temperature among cardinal directions and years on European mountain summits in the Mediterranean (number of regions $N_{reg} = 4$, number of summits $N_{sum} = 15$), temperate ($N_{reg} = 8$, $N_{sum} = 32$), and boreal biomes ($N_{reg} = 5$, $N_{sum} = 20$). Temperature represents values of hourly measurements above a threshold of 3 °C summed up during the growing season (May to September) of the years 2002 to 2007. Gaps in temperature measurement series were filled through imputation. This process was repeated 30 times. Models for each of the 30 imputed datasets and mean estimates \pm standard error and t-values were calculated (for details see text). P-values are derived from the mean t-value, p-values below 0.05 are given in bold. To allow for comparisons between each pairwise combination of cardinal directions we re-fitted the models with different cardinal directions as baseline level, which is given first in the table. Intercepts, year and the interaction between year and cardinal direction are not included in the table to enhance clarity (for full model results see Table 1).

	Mediterranean			Temperate			Boreal		
	estimate \pm SE	t-value	p-value	estimate \pm SE	t-value	p-value	estimate \pm SE	t-value	p-value
East - South	-0.01 \pm 0.04	-0.28	0.781	0.02 \pm 0.03	0.58	0.561	0.00 \pm 0.04	-0.02	0.983
East - West	-0.10 \pm 0.04	-2.55	0.011	-0.08 \pm 0.03	-2.67	0.008	-0.07 \pm 0.04	-1.58	0.114
East - North	-0.15 \pm 0.04	-3.83	<0.001	-0.16 \pm 0.03	-5.21	<0.001	-0.14 \pm 0.04	-3.21	0.001
South - West	-0.09 \pm 0.04	-2.37	0.019	-0.10 \pm 0.03	-3.21	0.001	-0.07 \pm 0.04	-1.54	0.125
South - North	-0.14 \pm 0.04	-3.69	<0.001	-0.18 \pm 0.03	-5.70	<0.001	-0.14 \pm 0.04	-3.14	0.002
West - North	-0.05 \pm 0.04	-1.24	0.216	-0.08 \pm 0.03	-2.54	0.011	-0.07 \pm 0.04	-1.65	0.100

Appendix S6 Fixed effects of (a) generalised linear mixed-effect models with binomial error distribution and logit link comparing vascular plant species richness, and (b) linear mixed-effect models comparing Shannon index between cardinal directions on European mountain summits in the Mediterranean (number of regions $N_{reg} = 7$, number of summits $N_{sum} = 25$), temperate ($N_{reg} = 16$, $N_{sum} = 62$), and boreal/polar biomes ($N_{reg} = 9$, $N_{sum} = 34$). To allow for comparisons between each pairwise combination of cardinal directions we re-fitted the models with different cardinal directions as baseline level, which is given first in the table. Intercepts are not included in the table to enhance clarity. P-values below 0.05 are given in bold.

	Mediterranean			Temperate			Boreal & Polar		
	estimate ± SE	z-value/ t-value	p-value	estimate ± SE	z-value/ t-value	p-value	estimate ± SE	z-value/ t-value	p-value
(a) Species Richness									
East - South	0.06±0.12	0.49	0.624	-0.06±0.06	-1.11	0.268	-0.09±0.11	-0.80	0.425
East - West	0.10±0.12	0.83	0.404	-0.44±0.06	-7.63	<0.001	-0.23±0.11	-1.98	0.047
East - North	-0.10±0.12	-0.86	0.391	-0.41±0.06	-7.10	<0.001	-0.31±0.11	-2.71	0.007
South - West	0.04±0.12	0.35	0.729	-0.38±0.06	-6.52	<0.001	-0.13±0.11	-1.19	0.235
South - North	-0.17±0.12	-1.35	0.178	-0.35±0.06	-5.98	<0.001	-0.22±0.11	-1.92	0.055
West - North	-0.21±0.12	-1.69	0.092	0.03±0.06	0.56	0.579	-0.08±0.11	-0.73	0.464
(b) Shannon Index									
East - South	0.01±0.12	0.06	0.952	-0.01±0.08	-0.15	0.879	-0.11±0.10	-1.09	0.277
East - West	0.12±0.12	0.99	0.326	-0.18±0.08	-2.15	0.033	-0.23±0.10	-2.31	0.023
East - North	0.12±0.12	1.00	0.323	-0.24±0.08	-2.92	0.004	-0.07±0.10	-0.67	0.508
South - West	0.11±0.12	0.93	0.357	-0.17±0.08	-1.99	0.049	-0.12±0.10	-1.22	0.227
South - North	0.11±0.12	0.94	0.353	-0.23±0.08	-2.74	0.007	0.04±0.10	0.42	0.678
West - North	0.01±0.12	0.03	0.978	-0.06±0.08	-0.72	0.471	0.16±0.10	1.62	0.110

Appendix S7 Fixed effects of binomial generalised linear mixed-effects models comparing (a) colonization, and (b) disappearance of species among cardinal directions on European mountain summits in the Mediterranean (number of regions $N_{\text{reg}} = 4$, number of summits $N_{\text{sum}} = 13$), temperate ($N_{\text{reg}} = 8$, $N_{\text{sum}} = 32$), and boreal ($N_{\text{reg}} = 5$, $N_{\text{sum}} = 19$) biomes. To allow for comparisons between each pairwise combination of cardinal directions we re-fitted the models with different cardinal directions as baseline level, which is given first in the table. Intercepts are not included in the table to enhance clarity. P-values below 0.05 are given in bold.

	Mediterranean			Temperate			Boreal		
	estimate ± SE	z-value	p-value	estimate ± SE	z-value	p-value	estimate ± SE	z-value	p-value
(a) Colonization									
East - South	0.47±0.35	1.35	0.176	-0.27±0.14	-1.9	0.058	-0.16±0.30	-0.52	0.605
East - West	-0.71±0.42	-1.67	0.095	-0.70±0.14	-4.87	<0.001	0.01±0.29	0.03	0.980
East - North	-1.15±0.47	-2.45	0.014	-0.87±0.15	-5.75	<0.001	0.05±0.28	0.19	0.847
South - West	-1.17±0.39	-2.98	0.003	-0.44±0.15	-2.88	0.004	0.16±0.30	0.55	0.586
South - North	-1.62±0.44	-3.65	<0.001	-0.60±0.16	-3.79	<0.001	0.21±0.29	0.73	0.464
West - North	-0.45±0.51	-0.88	0.378	-0.17±0.16	-1.02	0.306	0.05±0.28	0.17	0.865
(b) Disappearance									
East - South	-0.61±0.34	-1.77	0.076	-0.57±0.18	-3.15	0.002	0.56±0.40	1.4	0.162
East - West	-0.57±0.36	-1.59	0.111	-0.39±0.19	-2.09	0.037	0.12±0.43	0.29	0.774
East - North	-0.02±0.32	-0.07	0.948	-0.29±0.18	-1.59	0.112	-0.25±0.50	-0.5	0.614
South - West	0.04±0.39	0.11	0.914	0.18±0.20	0.9	0.368	-0.44±0.39	-1.11	0.268
South - North	0.59±0.36	1.65	0.1	0.28±0.20	1.44	0.149	-0.81±0.46	-1.75	0.081
West - North	0.55±0.37	1.47	0.142	0.10±0.20	0.51	0.612	-0.38±0.49	-0.77	0.443