Supporting Information

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Temperature Data

To obtain climate data for the years of historical surveys, we downscaled the 0.5° gridded time series of mean monthly temperatures from the University of East Anglia (CRU TS 3.10, ref. 1) for the whole Alpine arc to a resolution of 100 × 100 m for the period 1900–2014. Therefore, we statistically downscaled the 1-km WorldClim data (average values for the period 1950–2000, available online at www.worldclim.org) to 100 × 100 m using the methods applied in Dullinger et al. (2). Using the CRU dataset, we subsequently calculated anomalies between the yearly values and the average values for the reference period 1950–2000 used by WorldClim at the original 0.5° resolution. These anomalies were then spatially interpolated to 100 × 100 m and added to the downscaled WorldClim climatic maps to create a time series of absolute values at 100 × 100 m resolution.

We then assigned each plot a mean decadal temperature, i.e., the mean annual temperature of the 10 y preceding the historical survey. Subsequently, historical air temperature positions of rear edges, optima, and leading edges were calculated in the same manner as historical elevational positions (see *Statistical Analyses*). The relations between elevational shifts of rear edges, optima, and leading edges and their respective historical temperature positions as well as between proportional changes of elevational range size, abundances, their sum, and the historical temperature optima of the species were determined with linear regression models using each range attribute separately as response variable and using temperature as predictor.

For characterizing air temperature change between the historical and recent survey by one parameter, we calculated the difference between historical and mean decadal temperature assigning all historical plots the average sampling year (i.e., 1952).

Correlations and Skewness of Elevational Shifts

We calculated Pearson's correlation coefficients of shifts of rear edges, optima, and leading edges. The dynamics of rear and leading edges were significantly correlated with optimum shifts (rear–optimum: paired Pearson's $r = 0.35$, df = 181, $t = 5.06$, $P < 0.001$; leading–optimum: paired Pearson's $r = 0.34$, df = 181, $t = 4.92$, $P < 0.001$, Fig. S6) but rear and leading edge shifts were uncorrelated (df = 181, $t = 1.54$, $P = 0.127$).

Skewness of species' historical and recent distributions was calculated using the function *skewness* as implemented in the R-package *moments* (3). Changes were then derived by subtracting the historical from the recent value for each species separately. The average skewness of elevational distributions did not change (Fig. S6), and there is hence no indication that a "lean" type of range dynamics, with optima shifting at a different pace than one or both of the limits (4, 5), is prevalent among these species.

Species-Specific Traits

We compiled, in total, 10,046 records of species-specific traits from our own measurements, the online database TRY (6–40), the Tundra Trait Team, and literature (41–55). In a first step, we assessed averages for each trait and species from all available records. Then we calculated a compound index based on these traits, for both persistence- and dispersal-related traits (herein-after named persistence and dispersal, respectively). Persistence was calculated as the first ordination axis using the function *dudi.mix* as implemented in the package *ade4* (56) on the traits dominance (five levels from scattered to dominant), life span (years), life strategy (competition, intermediate, stress), and number of vegetative offsprings per year (count). High values represent long-living, dominant, and competitive species that produce high numbers of vegetative offsprings. For dispersal, we first calculated seed retention times in several types of animal fur and seed survival in guts based on the traits seed surface structure and seed mass following Römermann et al. (52) and Mouissie et al. (57). Analogous to persistence, we then calculated dispersal as the first ordination axis using the function *dudi.pca* as implemented in the package *ade4* (56) on the traits terminal velocity (m/s), retention in fur of cattle, deer, rabbit, horse, sheep, and bear (% of seeds remaining in fur after 1 h), gut survival (reduction in germination rate), and seed release height (centimeters). Low values represent species that can disperse over longer distances more easily. We then tested for significant relationships between these two indicators and rear edge, optimum, and leading edge shifts, respectively, using linear regression models.

Pasture Data

We derived proportional areas used as pastures in decadal time steps from "The History Database of the Global Environment" (HYDE v. 3.1, refs. 58 and 59) provided by the Netherlands Environmental Assessment Agency with a spatial resolution of 5′. For our analyses, we used the decadal value of 1950 for all historical plots (see *Temperature Data*) and calculated proportional changes by subtracting the historical from the most recent value (2005) and dividing it by the historical. To analyze whether proportional changes of the area used as pasture were significantly different from zero, we applied an intercept-only linear regression model (df = 1,548, $t = -302.80$, $P < 0.001$).

Community Density, Community Richness, and Turnover of Cooccurring Species

Changes of community density were calculated as the difference between the recent and the historical total cover (in percent) of vascular plant species per plot. Changes in community richness were computed as the difference in the total number of vascular plant species per plot. For these analyses, we used all 1,070 recorded species. Changes of community density could only be calculated for 860 plots, since this information was not reported for all of the historical plots. Turnover of cooccurring species between the historical and the recent surveys was calculated for those 183 plant species for which whole range dynamics were available (but all species are considered to be potential cooccurring species of the 183 target species). Based on presence/absence data of species cooccurring with a focal species in any plot, we calculated Bray–Curtis dissimilarities using the function *vegdist* as implemented in the package *vegan* (60). Whether relations between changes of density and richness per plot and plot elevation as well as between turnover of cooccurring species per species and the historical optimum of the species were significant was tested with linear regression models.

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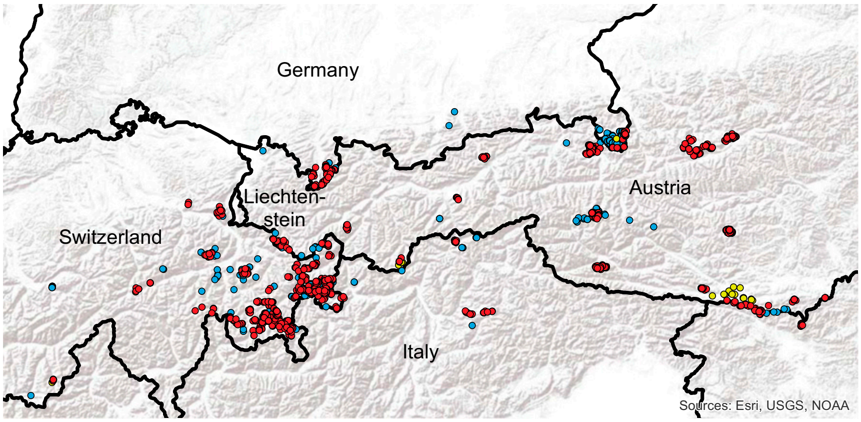

Fig. S1. Geographical distribution of plots; 1,549 resurveyed plots were used for plot-related analyses (red), 27 plots were resurveyed but not included in plot-related analyses (yellow, i.e., in total 1,576 resurveyed plots), and 435 plots were relocated but not resurveyed (blue), totaling 2011 relocated plots from 26 original publications (1–26).

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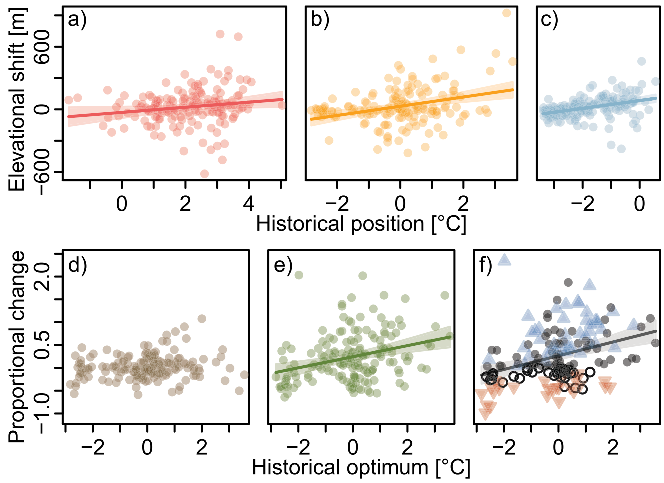

Fig. S2. Relationships between changes of range attributes and the historical ambient air temperature of these attributes for 162 mountain plant species of the European Alps. (*A*) Rear edges, (*B*) optima, (*C*) leading edges, (*D*) elevational range size, (*E*) abundance, and (*F*) sum of proportional elevational range size and abundance changes. Lines and their shades represent significant linear regression models (Table S2) with their confidence intervals. In *F*, blue pyramids depict winners (i.e., species with increased elevational ranges and increased abundances), red inverted pyramids depict losers (i.e., those with decreases in both of these range attributes), and dots symbolize species which combine loss in one attribute with gain in the other one. Closed darker dots can be considered as net winners (gain in one attribute > loss in the other one), and open dots can be considered as net losers (gain in one attribute < loss in the other one). Panels differ in size due to differing temperature ranges of the respective historical positions.

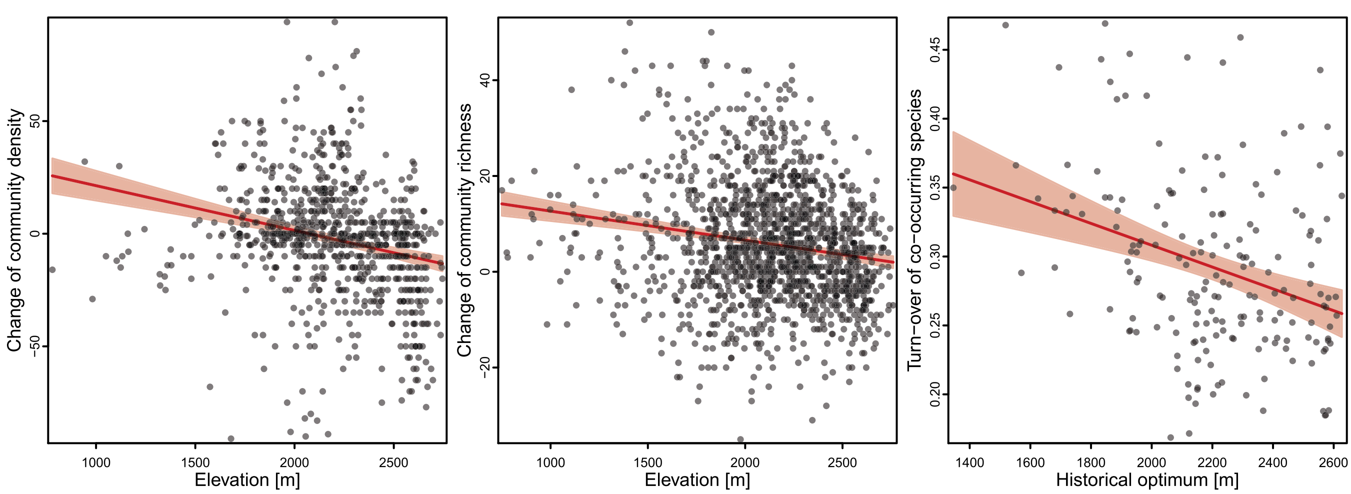

Fig. S3. Relationships between community changes and elevation. Lines and their shades represent significant linear regression models (Table S3) with their confidence intervals. Change of community density is based on the total vascular plant cover (in percent) of 860 resurveyed plots; change of community richness on the total number of vascular plant species of 1,549 resurveyed plots; turnover of cooccurring species was computed for those 183 mountain plant species for which elevational range dynamics could be calculated. Individual records are depicted as grey dots and are darker with more records at the same position.

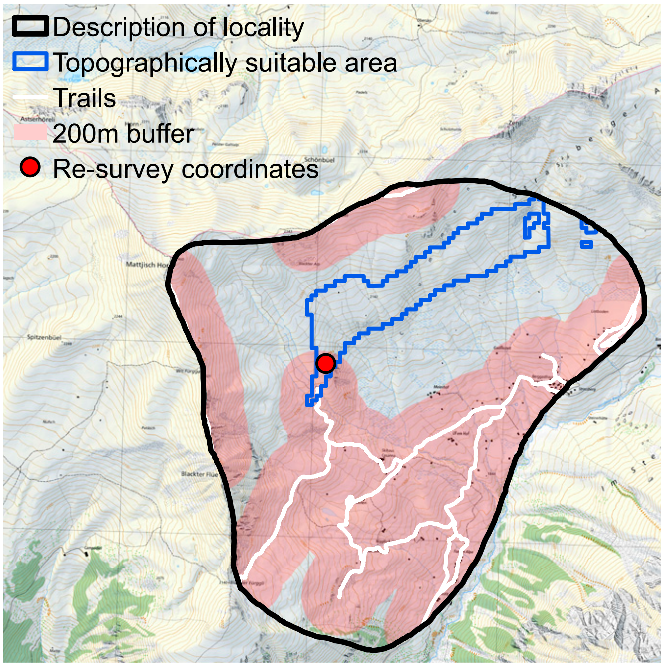

Fig. S4. Relocation design exemplified for one plot. Topographic background map is derived from the Federal Office of Topography swisstopo, available online at www.swisstopo.ch.

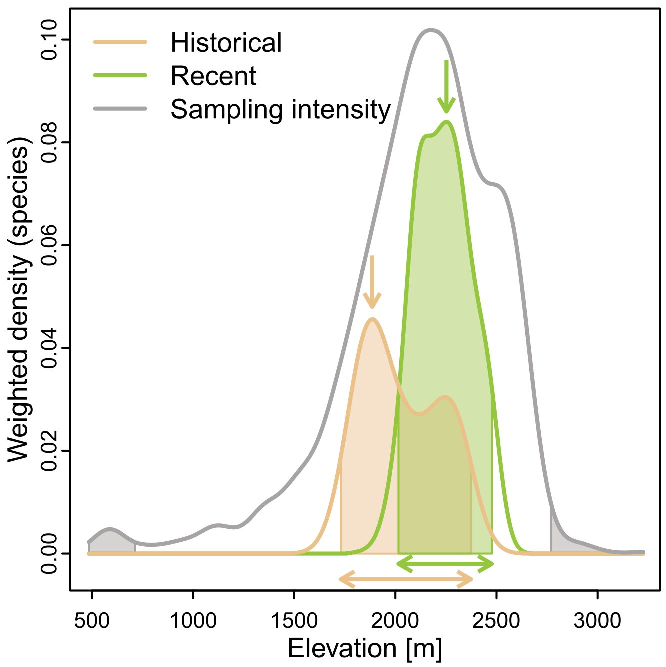

Fig. S5. Schematic illustration of the calculation of range attributes. Colored lines represent calculated density distributions of the species; the gray line represents the density distribution of the sampling intensity with reduced density values to fit the plot. Species abundance is defined as the sum of all density values below the respective curve, i.e., as the "integral" of the density distribution. Areas between the 5% and 95% quantiles of the species abundance are shaded in color, with their lower vertical boundary representing the species' rear edge and the upper vertical boundary representing its leading edge. Vertical arrows show the position of the species' optimum, i.e., the adapted density distributions' peak. Horizontal arrows depict the species' elevational range size. Gray shaded areas depict the 1% and 99% quantile of the sampling intensities distribution.

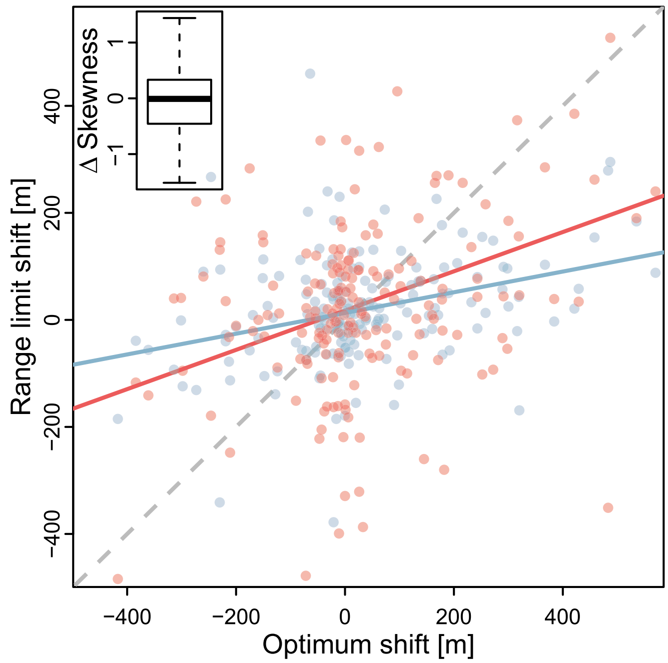

Fig. S6. Relationships between elevational shifts of range limits and optima for 183 mountain plant species of the European Alps. Rear edge shifts are depicted as red dots, and leading edge shifts are depicted as blue dots. Lines in the respective colors represent linear regression models. Dots above the diagonal dashed line represent species with range limits shifting faster than their optimum and below those with faster optimum shifts. (*Inset*) The boxplot depicts changes of optimum skewness.

Table S1. Changes of range attributes for 183 mountain plant species of the European Alps

Species	Rear edge shift, m	Optimum shift, m	Leading edge shift, m	Proportional elevational range size change	Proportional abundance change
Achillea atrata	373	316	−21	−0.31	0.26
Achillea clavennae	59	10	−38	−0.09	0.14
Acinos alpinus	−44	−39	21	0.07	0.77
Adenostyles alliariae	−122	17	−46	0.12	1.10
Agrostis alpina	−11	7	−60	−0.07	0.60
Ajuga pyramidalis	−141	−361	−56	0.10	0.65
Androsace chamaejasme	−24	6	−21	0.00	0.34
Androsace obtusifolia	−32	−213	−78	−0.08	0.08
Anemonastrum narcissiflorum	262	458	154	−0.15	0.70
Arabis bellidifolia s.lat.	−280	182	98	0.43	0.21
Arabis caerulea	−28	39	3	0.07	0.54
Arctostaphylos alpinus	158	38	−1	−0.28	−0.45
Arctostaphylos uva-ursi	285	367	103	−0.28	0.48
Arenaria ciliata s.str.	−70	−12	−8	0.10	−0.37
Aster alpinus	−3	−18	−15	−0.01	−0.44
Avenella flexuosa	−28	206	106	0.22	0.10
Avenula versicolor	−67	63	22	0.11	0.14
Bartsia alpina	39	384	−3	−0.05	0.35
Betonica alopecuros	132	−21	−378	−0.49	0.40
Botrychium lunaria	63	102	31	−0.03	0.08
Calamagrostis villosa	−62	−11	−4	0.13	0.00
Campanula barbata	125	16	−10	−0.16	0.05
Carduus defloratus s.lat.	0	−159	−34	−0.03	0.83
Carex atrata agg.	−109	−43	6	0.16	0.66
Carex capillaris	−95	−298	−124	−0.03	0.42
Carex ericetorum	−75	−71	−58	0.02	−0.34
Carex ferruginea	527	487	295	−0.19	0.72
Carex firma	16	31	−18	−0.05	0.15
Carex mucronata	−399	−11	55	0.59	−0.50
Carex ornithopoda agg.	−151	−90	−42	0.11	1.29
Carex rupestris	22	−71	−75	−0.20	−0.64
Carex sempervirens	−24	−79	−56	−0.04	0.57
Cerastium arvense	85	80	81	0.00	0.12
Cerastium carinthiacum	−387	33	24	0.58	−0.04
Cerastium uniflorum	156	319	43	−0.24	0.11
Chaerophyllum villarsii	283	−175	−57	−0.41	0.95
Chamorchis alpina	−73	−82	112	0.34	−0.47
Cirsium acaule	78	13	126	0.08	0.94
Cirsium spinosissimum	−163	−21	38	0.31	2.03
Coeloglossum viride	−171	−38	−1	0.27	1.11
Crepis jacquinii s.lat.	−260	145	−25	0.35	−0.48
Cystopteris fragilis	12	−121	82	0.09	−0.05
Daphne mezereum	44	291	99	0.07	0.43
Daphne striata	35	−219	−28	−0.10	0.05
Dianthus sylvestris	12	−23	44	0.04	−0.46
Draba aizoides agg.	87	−22	−63	−0.20	−0.11
Draba hoppeana	89	−10	−2	−0.36	−0.20
Dryas octopetala	93	24	22	−0.10	0.25
Empetrum nigrum agg.	81	1	53	−0.06	−0.10
Erigeron alpinus agg. (incl. *uniflorus*)	111	6	−11	−0.13	−0.29
Euphrasia minima	225	−219	−40	−0.26	0.32
Euphrasia officinalis	50	−20	186	0.21	1.59
Euphrasia salisburgensis	−162	−33	51	0.26	0.82
Festuca alpina	−46	75	71	0.16	0.07
Festuca halleri agg.	−24	−47	133	0.27	0.50
Festuca pumila	16	−55	−61	−0.11	0.49
Festuca varia agg.	96	99	−121	−0.22	0.56
Festuca violacea agg.	−219	−3	−31	0.26	0.36
Galium pusillum agg.	21	−15	−17	−0.04	0.46
Gentiana acaulis	68	−55	34	−0.04	0.08
Gentiana brachyphylla	−82	−69	11	0.23	−0.19

Table S1. Cont.

Species	Rear edge shift, m	Optimum shift, m	Leading edge shift, m	Proportional elevational range size change	Proportional abundance change
Gentiana nivalis	161	60	−2	−0.17	−0.31
Gentiana orbicularis	−158	0	−52	0.27	−0.46
Gentiana punctata	−7	−26	7	0.02	0.02
Gentianella anisodonta	269	168	226	−0.07	0.64
Gentianella aspera	54	−10	230	0.31	−0.17
Gentianella campestris	158	−151	78	−0.09	−0.19
Geranium sylvaticum	−27	137	71	0.11	0.42
Geum montanum	97	−14	69	−0.03	0.25
Globularia nudicaulis	−484	−417	−185	0.33	0.39
Gnaphalium hoppeanum/supinum	216	258	13	−0.24	−0.05
Hedysarum hedysaroides	−37	−34	−65	−0.04	0.10
Helianthemum alpestre	81	59	−13	−0.13	0.10
Heracleum austriacum	40	−314	−93	−0.17	1.35
Hieracium alpinum	77	243	80	0.00	−0.12
Hieracium glanduliferum	−182	6	31	0.39	−0.30
Hieracium lactucella	2	163	76	0.10	−0.54
Hieracium pilosum/villosum	53	−68	202	0.19	−0.24
Homogyne alpina	−20	179	49	0.09	0.43
Homogyne discolor	256	216	163	−0.15	2.02
Huperzia selago	316	26	128	−0.19	−0.33
Hypochaeris uniflora	34	429	58	0.04	−0.28
Juncus jacquinii	35	−7	−26	−0.12	0.18
Juncus monanthos	41	−301	−1	−0.05	1.54
Juncus trifidus	120	−12	52	−0.10	0.00
Juniperus communis	110	122	65	−0.07	0.24
Kobresia myosuroides	−64	−35	−17	0.09	−0.24
Laserpitium halleri	−89	−124	−96	−0.01	−0.41
Leontodon helveticus	30	−10	37	0.01	0.43
Leontodon montanus	2	131	98	0.13	−0.07
Leontopodium alpinum	60	−7	−42	−0.12	−0.40
Ligusticum mutellina	−31	−148	−105	−0.09	0.79
Ligusticum mutellinoides	66	−45	−104	−0.25	−0.03
Loiseleuria procumbens	104	−23	113	0.02	−0.22
Lonicera caerulea	−3	−16	−185	−0.34	−0.54
Luzula alpinopilosa	51	73	206	0.31	0.82
Luzula lutea	256	165	22	−0.31	0.08
Luzula sylvatica	−222	−47	−109	0.19	0.25
Minuartia verna agg.	−5	10	11	0.02	−0.20
Myosotis alpestris	−29	−42	5	0.03	0.10
Myosotis sylvatica	124	−71	48	−0.12	−0.31
Nigritella nigra agg.	−19	−33	102	0.20	−0.20
Oxalis acetosella	−329	0	−179	0.24	−0.03
Oxytropis campestris	−161	−13	−66	0.16	−0.42
Oxytropis montana agg.	−24	−12	54	0.12	0.28
Pedicularis aspleniifolia	111	7	−82	−0.57	−0.42
Pedicularis rostratocapitata	42	14	−24	−0.08	−0.19
Pedicularis tuberosa	178	52	131	−0.08	−0.36
Pedicularis verticillata	185	300	25	−0.19	−0.26
Persicaria vivipara	9	160	−17	−0.03	0.12
Peucedanum ostruthium	−24	20	−155	−0.17	0.93
Phleum alpinum agg.	−54	298	96	0.21	0.74
Phleum hirsutum	131	−230	−341	−0.53	0.30
Phyteuma betonicifolium	58	179	−65	−0.17	−0.11
Phyteuma hemisphaericum	9	−142	26	0.03	−0.03
Phyteuma sieberi	−71	50	59	0.26	−0.34
Pinus mugo agg.	−617	−128	−139	0.72	0.73
Plantago alpina	145	−150	113	−0.03	0.81
Plantago atrata	46	320	−169	−0.27	0.69

Table S1. Cont.

Species	Rear edge shift, m	Optimum shift, m	Leading edge shift, m	Proportional elevational range size change	Proportional abundance change
Plantago strictissima	20	−32	240	0.40	0.53
Poa nemoralis	5	−64	460	1.08	0.15
Polygala alpestris	−21	−169	9	0.04	0.31
Potentilla aurea	64	−132	4	−0.07	0.58
Potentilla brauneana	695	923	121	−0.50	1.59
Potentilla crantzii	−117	−384	−39	0.08	−0.09
Potentilla grandiflora	43	243	−16	−0.07	−0.33
Primula auricula	−75	171	9	0.09	−0.56
Primula hirsuta	−168	1	−52	0.21	0.00
Primula integrifolia	93	25	−66	−0.27	−0.15
Primula minima	−34	−48	−10	0.04	0.03
Primula wulfeniana	−11	−200	−13	0.00	0.05
Pseudorchis albida	102	−7	34	−0.10	−0.28
Pulsatilla alpina s.lat.	336	2	−12	−0.43	−0.17
Pulsatilla vernalis	270	190	50	−0.26	0.09
Ranunculus alpestris	385	421	21	−0.30	0.21
Ranunculus hybridus	−63	45	33	0.15	0.22
Rhinanthus glacialis	−351	483	279	0.79	0.24
Rhododendron ferrugineum	6	37	73	0.14	0.29
Rhododendron hirsutum	73	139	73	0.00	1.05
Rumex alpestris	3	−54	17	0.01	0.78
Rumex scutatus	38	178	177	0.13	−0.05
Salix alpina	−95	103	129	0.48	−0.55
Salix reticulata	721	192	−57	−0.59	1.11
Salix retusa agg.	335	−45	−16	−0.34	0.37
Saponaria pumila	136	232	33	−0.21	0.00
Saussurea alpina	−220	27	−8	0.44	−0.57
Saxifraga aizoides	−102	252	155	0.44	1.35
Saxifraga androsacea	768	71	2	−0.52	−0.31
Saxifraga caesia	94	6	21	−0.09	−0.04
Saxifraga paniculata	427	96	−29	−0.36	−0.20
Saxifraga rudolphiana	323	62	2	−0.69	0.15
Selaginella selaginoides	−16	76	−73	−0.06	0.83
Sempervivum montanum	27	154	8	−0.03	0.33
Senecio abrotanifolius	−205	−43	67	0.40	0.30
Senecio carniolicus	132	−8	−68	−0.33	0.27
Sesleria ovata	184	−8	−26	−0.40	−0.41
Sesleria sphaerocephala	−93	272	148	0.49	−0.42
Sibbaldia procumbens	145	−229	94	−0.07	−0.08
Silene acaulis s.lat.	9	−2	17	0.01	0.17
Silene alpestris	190	535	184	−0.01	0.90
Silene rupestris	91	52	25	−0.08	−0.34
Soldanella alpina	39	90	−159	−0.20	1.03
Soldanella minima agg.	240	570	88	−0.20	1.52
Soldanella pusilla	120	−53	−50	−0.22	0.25
Thesium alpinum	−107	−22	5	0.12	0.11
Thlaspi rotundifolium	11	30	33	0.03	−0.21
Trifolium alpinum	190	135	72	−0.16	−0.06
Trifolium badium	−248	−211	−113	0.23	0.63
Trifolium thalii	−100	114	14	0.14	0.21
Trisetum alpestre	−14	15	96	0.30	1.00
Trollius europaeus	−66	125	47	0.11	0.39
Vaccinium myrtillus	−34	289	57	0.16	0.29
Vaccinium uliginosum agg.	173	−5	81	−0.14	0.02
Valeriana celtica	52	2	12	−0.08	0.32
Valeriana montana	−478	−72	75	0.59	0.60
Valeriana tripteris	−179	−246	267	0.90	0.13
Veronica alpina	−19	57	−8	0.01	0.00
Veronica aphylla	221	−273	−131	−0.29	1.39

Table S1. Cont.

Species	Rear edge shift, m	Optimum shift, m	Leading edge shift, m	Proportional elevational range size change	Proportional abundance change
Veronica bellidioides	244	18	11	−0.28	−0.34
Veronica fruticans	81	−260	90	0.01	0.31
Veronica serpyllifolia	−321	26	99	0.64	0.33
Viola biflora	54	−13	42	−0.01	0.60
Viola calcarata	33	25	24	−0.01	0.25

Nomenclature follows Fischer et al. (1), supplemented by Lauber et al. (2).

1. Fischer MA, Oswald K, Adler W (2008) *Exkursionsflora für Österreich, Liechtenstein und Südtirol* (Biologiezentrum Oberösterreichischen Landesmuseen, Linz, Austria), 3rd Ed.
2. Lauber K, Wagner G, Gygax A (2012) *Flora Helvetica* (Haupt, Bern, Switzerland), 5th Ed.

Table S2. Relationships between changes of range attributes and different predictor variables for mountain plant species of the European Alps

Range attribute	Predictor variable	Effect ± SE	df	*t* value	*P* value	R^2
Elevation						
Rear edge shift, m	(Intercept)	320.8 ± 94.3				
	Historical rear edge, m	−0.2 ± 0.1	181	−3.12	0.002	0.05
Optimum shift, m	(Intercept)	642.1 ± 103.0				
	Historical optimum, m	−0.3 ± 0.0	181	−5.94	<0.001	0.16
Leading edge shift, m	(Intercept)	550.7 ± 93.8				
	Historical leading edge, m	−0.2 ± 0.0	181	−5.68	<0.001	0.15
Proportional elevational range size change	(Intercept)	0.3 ± 0.2				
	Historical optimum, m	$-1.3^{e-4} \pm 0.8^{e-4}$	181	−1.78	0.076	0.01
Proportional abundance change	(Intercept)	1.5 ± 0.3				
	Historical optimum, m	$-6.0^{e-4} \pm 1.4^{e-4}$	181	−4.26	<0.001	0.09
Sum of proportional elevational range size and	(Intercept)	1.9 ± 0.3				
proportional abundance changes	Historical optimum, m	$-7.4^{e-4} \pm 1.6^{e-4}$	181	−4.70	<0.001	0.10
Air temperature						
Rear edge shift, m	(Intercept)	−28.7 ± 27.3				
	Historical rear edge, °C	24.5 ± 11.5	160	2.13	0.035	0.02
Optimum shift, m	(Intercept)	30.0 ± 13.3				
	Historical optimum, °C	44.1 ± 9.8	160	4.51	<0.001	0.11
Leading edge shift, m	(Intercept)	84.4 ± 14.9				
	Historical leading edge, °C	37.4 ± 7.3	160	5.14	<0.001	0.14
Proportional elevational range size change	(Intercept)	$2.2^{e-2} \pm 2.1^{e-2}$				
	Historical optimum, °C	$2.9^{e-2} \pm 1.5^{e-2}$	160	1.92	0.056	0.02
Proportional abundance change	(Intercept)	$24.3^{e-2} \pm 4.0^{e-2}$				
	Historical optimum, °C	$12.2^{e-2} \pm 3.0^{e-2}$	160	4.12	<0.001	0.09
Sum of proportional elevational range size and	(Intercept)	$26.5^{e-2} \pm 4.3^{e-2}$				
proportional abundance changes	Historical optimum, °C	$15.1^{e-2} \pm 3.1^{e-2}$	160	4.82	<0.001	0.12
Temperature indicator value						
Rear edge shift, m	(Intercept)	150.5 ± 45.2				
	Temperature indicator	−67.9 ± 24.1	176	−2.82	0.005	0.04
Optimum shift, m	(Intercept)	30.5 ± 44.4				
	Temperature indicator	2.9 ± 23.7	176	0.12	0.903	0.00
Leading edge shift, m	(Intercept)	−35.5 ± 24.6				
	Temperature indicator	31.2 ± 13.1	176	2.37	0.019	0.03
Proportional elevational range size change	(Intercept)	$-24.5^{e-2} \pm 6.3^{e-2}$				
	Temperature indicator	$14.4^{e-2} \pm 3.4^{e-2}$	176	4.25	<0.001	0.09
Proportional abundance change	(Intercept)	$9.2^{e-2} \pm 12.7^{e-2}$				
	Temperature indicator	$7.2^{e-2} \pm 6.8^{e-2}$	176	1.06	0.289	0.00
Sum of proportional elevational range size and	(Intercept)	$-15.3^{e-2} \pm 14.0^{e-2}$				
proportional abundance changes	Temperature indicator	$21.6^{e-2} \pm 7.5^{e-2}$	176	2.90	0.004	0.04
Nutrient indicator value						
Rear edge shift, m	(Intercept)	49.5 ± 51.6				
	Nutrient indicator	−8.6 ± 23.1	179	−0.37	0.710	0.00
Optimum shift, m	(Intercept)	−13.4 ± 49.2				
	Nutrient indicator	21.6 ± 22.0	179	0.98	0.328	0.00
Leading edge shift, m	(Intercept)	42.0 ± 27.9				
	Nutrient indicator	−10.6 ± 12.5	179	−0.85	0.396	0.00
Proportional elevational range size change	(Intercept)	$-1.3^{e-2} \pm 7.4^{e-2}$				
	Nutrient indicator	$1.0^{e-2} \pm 3.3^{e-2}$	179	0.29	0.775	0.01
Proportional abundance change	(Intercept)	$-46.8^{e-2} \pm 13.4^{e-2}$				
	Nutrient indicator	$31.9^{e-2} \pm 6.0^{e-2}$	179	5.34	<0.001	0.13
Sum of proportional elevational range size and	(Intercept)	$-48.0^{e-2} \pm 15.1^{e-2}$				
proportional abundance changes	Nutrient indicator	$32.9^{e-2} \pm 6.8^{e-2}$	179	4.86	<0.001	0.11
Persistence- and dispersal-related traits						
Rear edge shift, m	(Intercept)	29.8 ± 13.9				
	Persistence	−7.2 ± 10.3	181	−0.69	0.489	0.00
Optimum shift, m	(Intercept)	33.9 ± 13.4				
	Persistence	1.0 ± 9.9	181	0.10	0.923	0.01

Table S2. Cont.

Range attribute	Predictor variable	Effect ± SE	df	*t* value	*P* value	R^2
Optimum shift, m	(Intercept)	33.9 ± 13.4				
	Dispersal	0.3 ± 8.5	181	0.03	0.973	0.01
Leading edge shift, m	(Intercept)	19.5 ± 7.5				
	Dispersal	−7.3 ± 4.7	181	−1.54	0.126	0.01

Relationships were calculated using linear regression models. The number of observations differs between predictor variables due to data availability. Temperature indicator values: 1, alpine to nival; 1.5, lower alpine to upper subalpine; 2, subalpine; 2.5, lower subalpine to upper montane; 3, montane; 3.5, lower montane to upper colline; 4, colline. Nutrient indicator values: 1, very nutrient-poor; 2, nutrient-poor; 3, moderately nutrient-poor to moderately nutrient-rich; 4, nutrient-rich.

Table S3. Relationships between community changes and elevation

Type of community change	Elevation	Effect ± SE	df	*t* value	*P* value	R^2
Change of community density	(Intercept)	41.2 ± 6.0				
	Plot elevation, m	$-2.0^{e-2} \pm 0.3^{e-2}$	858	−7.36	<0.001	0.06
Change of community richness	(Intercept)	18.7 ± 1.9				
	Plot elevation, m	$-6.1^{e-3} \pm 0.9^{e-3}$	1,547	−6.88	<0.001	0.03
Turnover of cooccurring species	(Intercept)	$4.7^{e-1} \pm 0.4^{e-1}$				
	Historical optimum, m	$-7.9^{e-5} \pm 1.7^{e-5}$	181	−4.60	<0.001	0.10

Change of community density is based on the total vascular plant cover (in percent) of 860 resurveyed plots; change of community richness is based on the total number of vascular plant species of 1,549 resurveyed plots; turnover of cooccurring species was computed for those 183 mountain plant species for which elevational range dynamics could be calculated.