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The sensitivity of plant interactions and species distribution in alpine snowbeds to climate change

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Alpine communities are especially susceptible to environmental changes (e.g. Theurillat and Guisan, 2001; Walker et al. 2006) and, therefore, they will probably show a considerable response to global climate warming (Guisan and Theurillat, 2000; Thuiller et al., 2005). Among alpine plant communities, snowbeds are regarded as particularly sensitive indicators of climate change (Björk and Molau, 2007). They are characterised by a long-lasting snow cover which is expected to shorten in the alpine zone due to climate change (Beniston et al., 2003). Therefore, changes in species composition in snowbeds can be expected. In my thesis the main question was: How will species composition and species number in alpine snowbeds change under new climatic conditions?

First, small-scale vascular plant species distribution along snowmelt and soil temperature gradients was studied in snowbeds in the Swiss Alps (Gemmi Pass, 2400 m a.s.l., **Fig. 1**). The results revealed a significant increase in species richness with earlier snowmelt and higher temperature (**Fig. 2**). The pattern of species occurrence along the snowmelt gradient allowed for a categorisation of species with predictions of their future distribution. Five different groups of species could be distinguished (Schöb et al., 2009): dominant, indifferent, and occasional species with very high, intermediate, and low frequency and abundance along the whole snowmelt gradient, respectively; further a group of subordinate snowbed species with a frequent distribution in late melting sites, and a group of grassland species avoiding late melting sites (**Fig. 2**). Therefore, the subordinate snowbed species were considered losers under climate change due to the probable loss of their habitat, whereas grassland species were considered profiteers due to their invasion of snowbeds.

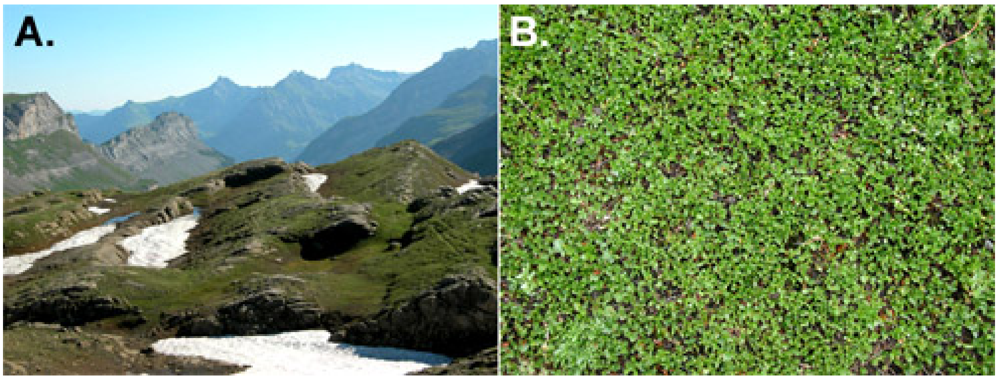

Figure 1. A. *Study site Lämmerenplatten, Leukerbad (VS), Switzerland. Thirty snowbeds were situated in an area of about 0.3 km^2 at 2400 m a.s.l.* ***B.*** *Snowbed communities were dominated by Salix herbacea, Alchemilla pentaphyllea and Gnaphalium supinum.*

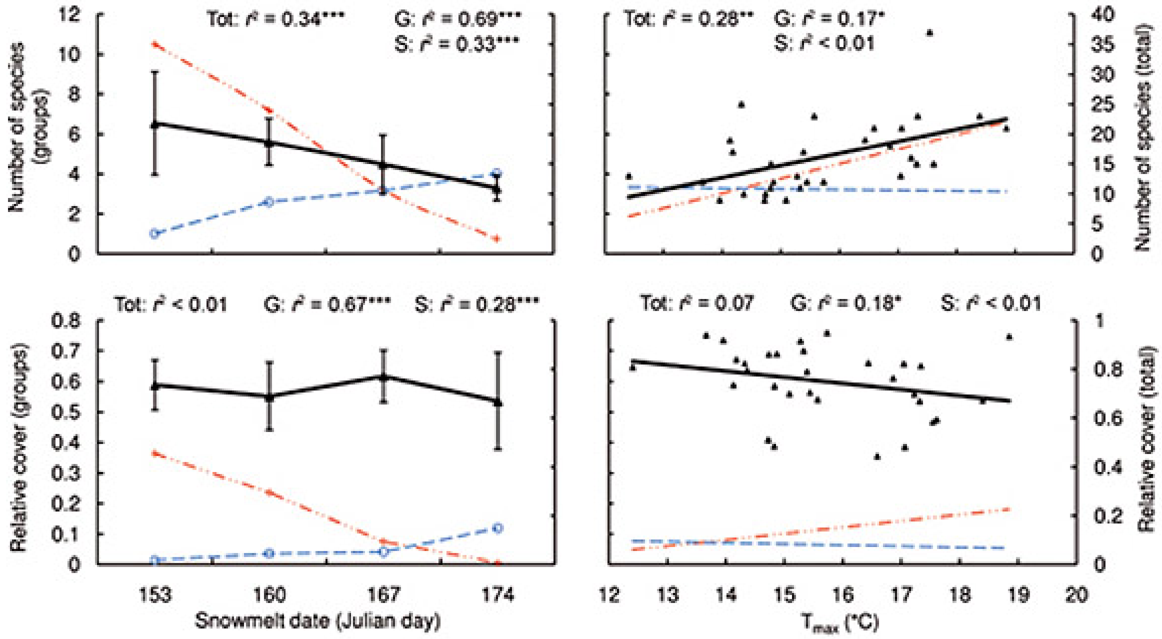

Figure 2. *Number of species and relative species cover along the snowmelt and temperature gradients for all species Tot (—▲—, right y-axis) and for two species groups (left y-axis): subordinate snowbed species S (– –○– –) and grassland species G (– • • –+– • • –). Error bars indicate ± 1 SD for each snowmelt date. * P<0.05, ** P<0.01, *** P<0.001. n for snowmelt date 153 (02.06.2003) = 6, 160 (09.06.2003) = 20, 167 (16.06.2003) = 18, 174 (23.06.2003) = 8. n for T_{max} = 31.*

Since successful invasion of grassland species into snowbeds will depend on the availability of susceptible microhabitats and plant-plant interactions, small-scale spatial patterns were analysed. It was hypothesised that selective colonisation of microhabitats as well as important plant-plant interactions will result in non-random spatial distribution of species at the very local scale. In general, aggregation was found within subordinate snowbed species and within grassland species, respectively, and segregation between the two groups (Schöb et al., 2008). From the results obtained, a probable existence of microhabitats with different susceptibility to invasion and a competition-based segregation of grassland and snowbed species could be derived. The conclusion was that the inability to cope with very short growing seasons restricted grassland species to the earlier melting sites. However, snowbed species seemed to be pushed back to the later-melting sites through competitive exclusion by grassland species under milder growing conditions.

Through neighbour removal experiments, the effects of plant-plant interactions on plant growth and survival were revealed for species with different distributional optima in snowbeds (**Fig. 3**). Plants growing without neighbours showed increased biomass and fruiting compared to the control individuals (**Fig. 4**). Therefore, in this alpine habitat with favourable growing conditions, apart from a short growing season, competition for resources generally prevailed (Schöb et al., in press). However, simultaneously occurring facilitation due to protection against herbivores resulted in a lower survival probability in removal plots (**Fig. 4**). Furthermore, neighbour effects were neither species-specific nor did they change along the snowmelt gradient. Therefore, competition for resources in snowbeds was generally counterbalanced by facilitative interactions against herbivores, leading the weak net effects for all species and snowmelt dates.

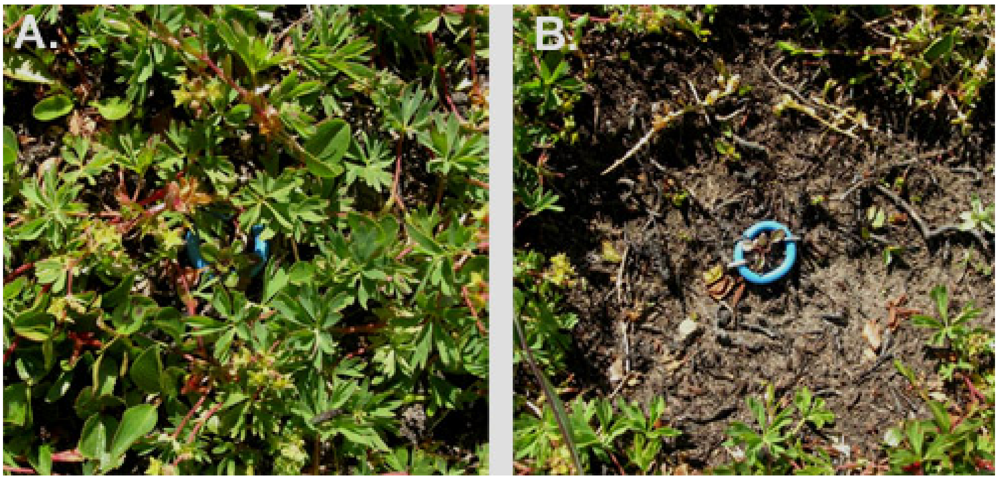

Figure 3. *Neighbour removal treatment for Cardamine alpina, a subordinate snowbed species.* ***A.*** *Control: Individual growing with neighbours.* ***B.*** *Removal: Individual growing without neighbours. For the removal treatment all aboveground biomass in a radius of 5 cm around the target individual was mechanically removed.*

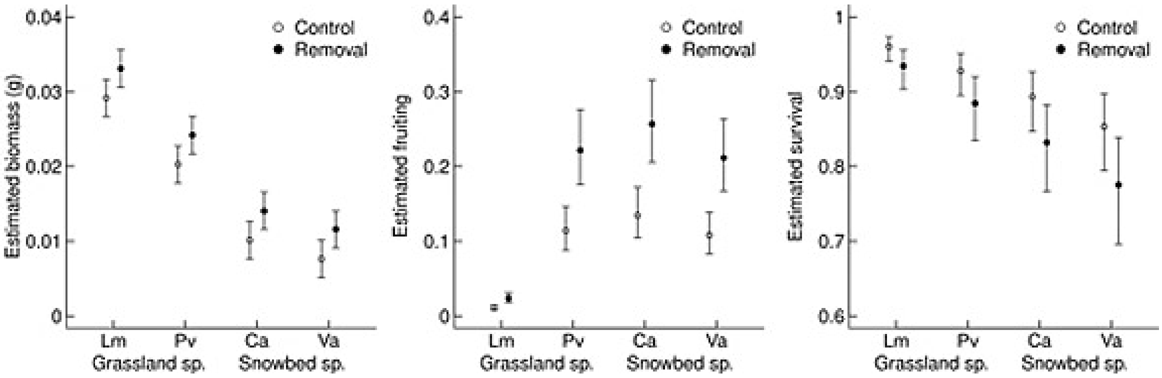

Figure 4. *The effects of neighbour removal on aboveground biomass, fruiting and survival rate for grassland species and snowbed species, respectively. Displayed are estimated means ± 1 SE of the linear mixed model (biomass) and generalised linear mixed models (fruiting and survival). Species: Lm = Ligusticum mutellina, Pv = Polygonum viviparum, Ca = Cardamine alpina, Va = Veronica alpina (dominant and indifferent species not shown). n for biomass = 382 (dead plants were omitted). n for fruiting = 788 (dead plants were omitted). n for survival = 960.*

As long as plant interactions of different sign are cancelling each other out, changes in abiotic conditions will most probably be the main driver for changes in species composition in alpine snowbeds. Since growing conditions in snowbeds will improve under future climate scenarios, an invasion of more competitive grassland species can be expected. This will induce a considerable change in species composition in snowbeds which may further lead to local extinction of subordinate snowbed species and could even globally threaten those restricted to snowbed habitats in South-European mountains. Successful predictions based on models considering only abiotic conditions could be misleading if the balance between positive and negative species interactions change due to environmental conditions (Schöb et al., in press).

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