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# Long-term changes in summit plant diversity in the Swiss National Park

**Sonja Wipf & Christian Rixen**

## Abstract

Botanical resurveys of mountain summits, based on historical species lists, demonstrate that species richness on summits in the Swiss National Park has strongly increased since the early 20th century. More detailed, but shorter-term monitoring of mountains summits according to the GLORIA show that species from lower altitudes are colonizing these summits. High colonization rates on the climatically favoured southern sides of summits are strongly correlated with high local extinction rates, which might indicate an increase in competition for space between plant species.

## Keywords

alpine plant species, biodiversity, climate change, GLORIA, Swiss National Park, upwards shifts

## Introduction

The Swiss National Park (SNP) was founded in 1914 as the first National Park in Central Europe. Since then, the protected perimeter served as a laboratory to investigate natural processes unaffected by current direct influence by humans. Thus, long-term monitoring of flora and fauna as well as of various ecosystem processes has a long tradition (HALLER et al. 2013).

## Methods

To establish a baseline for the monitoring of alpine plant distribution in the European Alps and specifically in the SNP, Josias Braun-Blanquet surveyed the plant species composition and altitudinal distribution of 14 summits in and around the SNP (BRAUN 1913, BRAUN-BLANQUET 1957, 1958). Moreover, two target sites (eight summits) according to the GLORIA monitoring scheme (PAULI et al. 2015) were installed in 2002/2003 (Tab. 1). Recent resurveys of species composition on these summits allow for quantification of floristic changes over the long term and the short term, whereas detailed repeat relevés in permanent plots on the GLORIA summits give insight into the processes leading to these changes.

| SN1 – calcareous bedrock | m a.s.l. | SN2 – siliceous bedrock | m a.s.l. |
|---|---|---|---|
| MBU – Munt Buffalora | 2438 | MCS – Munt sper Chamonna Sesvenna | 2424 |
| MCH – Munt Chavagl | 2542 | MIN - Minschuns | 2519 |
| PMU – Piz Murter | 2836 | MDG – Mot dal Gajer | 2797 |
| PFO – Piz Foraz | 3092 | PPL – Piz Plazér | 3104 |

Table 1: GLORIA summits of the two target sites in the SNP region

## Results and Discussion

The comparison of historical and recent surveys on 14 summits showed a clear increase in species maximum altitudes, an influx of species typical for lower altitudes, and an increase of species numbers (WIPF et al. 2013): on average, the highest occurrence of species that were present both historically and recently moved uphill by 92 m. Additionally, 38 species (out of a total of 139 species) were new to these 14 summits. Although the summits were all located clearly above treeline at altitudes between 2797 and 3412 m asl., 20% of the newly appeared species have their main distribution below treeline (according to LANDOLT et al. 2010). Due to this influx of new species, the average species number on a summit (10 altitude m below top) increased by 44% since the early 20th century, from 15.1 to 21.8 species per summit (Fig. 1).

The limiting effect of cold temperatures on the occurrence of many plant species is clearly visible from a steep decrease in species richness with increasing altitude (Fig. 1), as well as from the generally larger number of species being able to grow at the warm, southern aspect than at the colder, northern side of summits (Fig. 2). Thus, when this limiting effect is diminishing due to climate warming as seen over past decades, alpine plant composition will obviously respond strongly. The trends in the long-term development of the SNP summit floras clearly correspond to those found in most mountain regions over Europe where such historical data is available (see RIXEN & WIPF 2017 for a recent review).

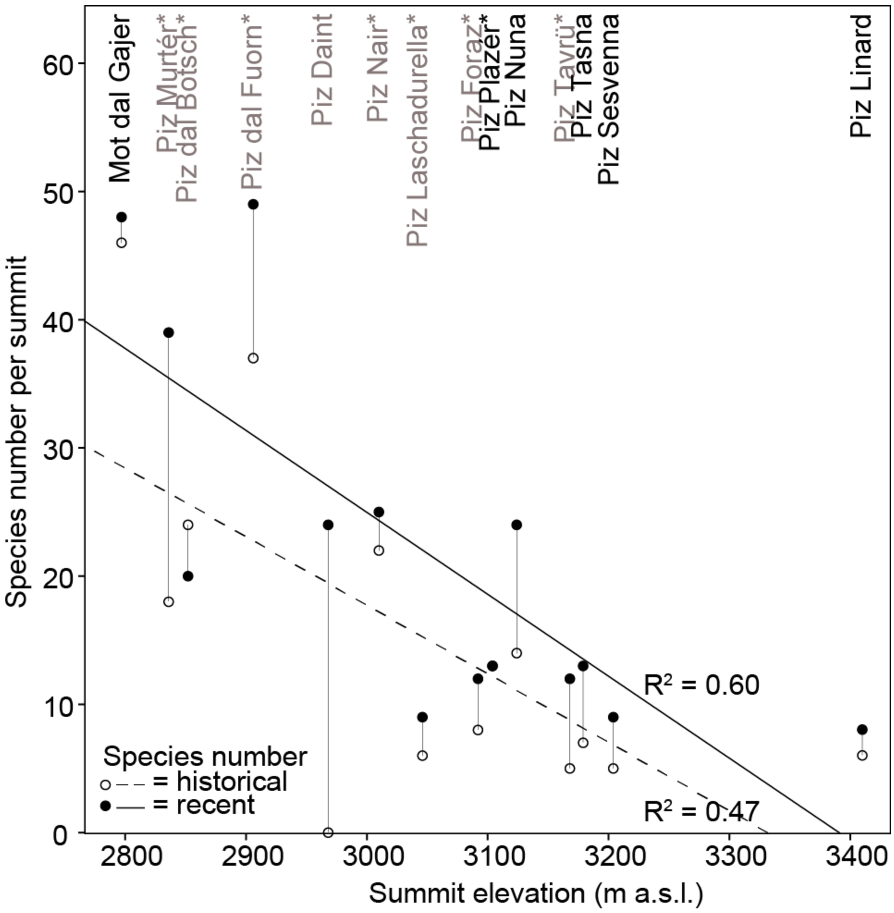


Figure 1: Species numbers increased over the 20th century on each of 14 summits in the region of the Swiss National Park. Names in grey denote summits on calcareous bedrock, asterisks mark summits that have very low visitor frequencies (as estimated from summit books, or because access is limited by park rules).

The shorter-term, but more detailed relevés on the eight GLORIA summits in the SNP region give insight into the processes taking place at a smaller spatial scale. Plot-level data indicate that the increase in species numbers mainly stems from an influx and increase of species with higher heat requirements than the previously present ones (WILD 2016). These incoming species from lower altitudes have their main distribution in montane and subalpine belts, where vegetation is generally more productive and thus competition within communities more severe than at higher altitudes. Thus, this influx of species is likely to result in higher competition pressure on cold-adapted species, especially at climatically favourable sites.

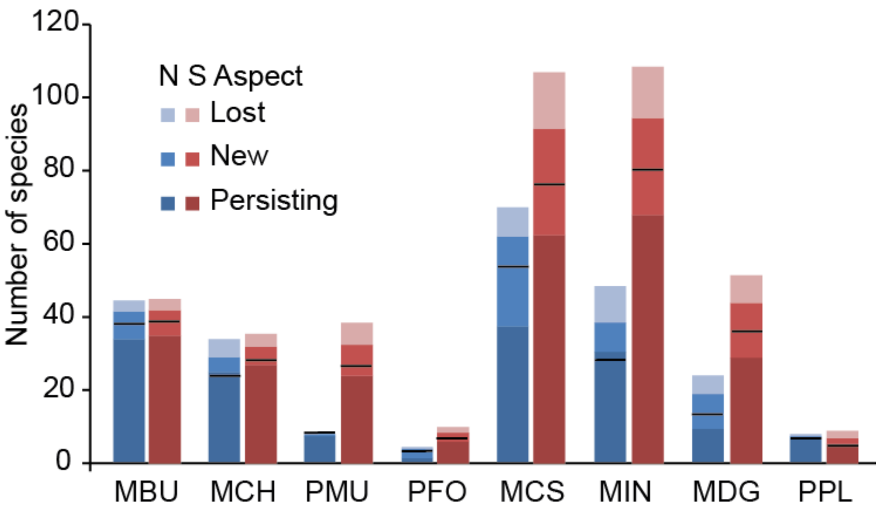


Figure 2: Number of species that persisted (dark), appeared newly (medium), or disappeared (light shade) between 2002/03 and 2015 on North (blue, left) and South (red, right) aspects of the SNP GLORIA summits. Species richness in 2015 indicated as black bars. Numbers are means of the two summit sections per aspect (0-5 and 5-10 m, see PAULI et al. 2015 for methods). Species richness is generally higher on S aspect than on N aspect, and has mostly increased over the monitoring period.

Our findings that the number of newly appearing and lost species since 2002/03 were higher in the warmer, south exposed than the colder, northern aspect (based on summit area sections, all paired t-test $p<0.05$; Fig. 2), could be an indication of this increased competition pressure. Also, there was a strong and significant correlation between the number of new and lost species, and this correlation was much steeper on the southern than on the northern aspect, suggesting an indirect or direct adverse effect of new colonizers on previously present species on the warm side of the summit. However, the number of newly appearing and lost species strongly correlated with species number (Fig. 3), i.e. the higher loss could simply be a random process with constant rates (and thus, higher losses in richer communities). Moreover, until now we found no indication that the lost species were especially cold adapted, as there was significant difference of temperature indicator values of lost vs. new or persisting species, results not shown).

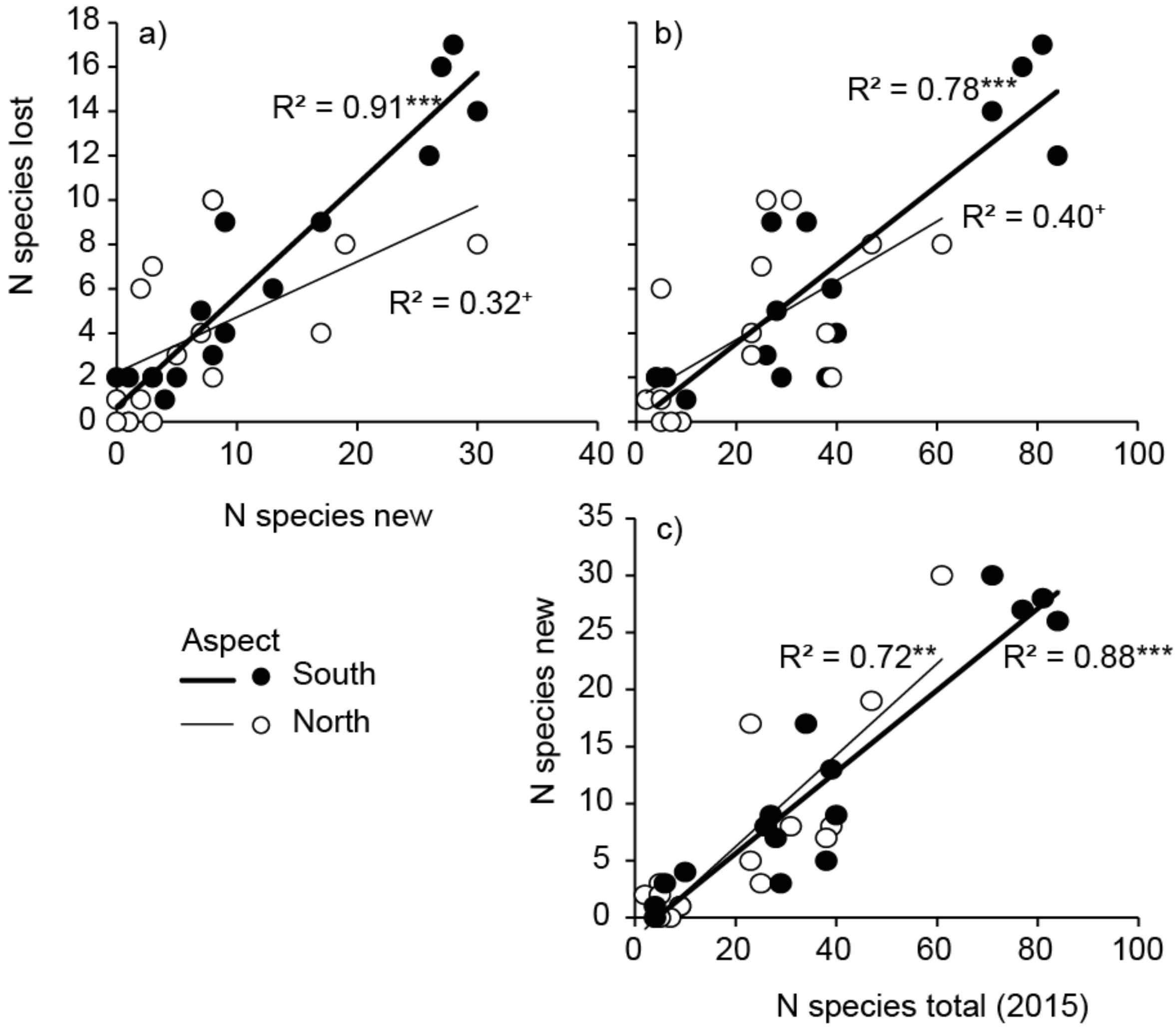


Figure 3: Correlations between lost and new (a), lost and total (b), and new and total species numbers per summit area section in the North and South aspects of 8 GLORIA summits. Significance of the correlations were calculated based on a per-aspect level (i.e. N=8; + $p<0.1$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$).

Small scale mapping of abiotic conditions and species distributions in alpine habitats indicate that the diversity of thermal microhabitats and soil types is very high (SCHERRER & KÖRNER 2011, KULONEN et al. in press), and that occurrences of plant species' microhabitats differentiate along such gradients. Whether, where, and which cold-adapted species will be able to escape the newly arriving competitors with higher heat requirements, might ultimately depend on the presence and long-term persistence of such microhabitat refugia.

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## Contact

Sonja Wipf, Christian Rixen
wipf@slf.ch; rixen@slf.ch
WSL Institute for Snow and Avalanche Research SLF
Flüelastrasse 11
7260 Davos Dorf
Switzerland