Changes in the spatial distribution of vascular plant species in the Southeastern Swiss Alps over the past century

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Over the course of the last 100 years, alpine conditions have changed dramatically in the Swiss Alps. Human land use practices, such as increased livestock grazing pressures, forest management practices, and increased tourism and high alpine recreation, have had a large influence on high mountain systems. Additionally, climatic processes have certainly had an effect on environmental conditions on mountain summits. Annual average temperature has increased by approximately 1–2°C over the past century and glaciers which previously covered large tracts in the Swiss Alps have retreated by an area of approximately 40% since 1850 (Haeberli and Beniston 1998). Why should we care about such changes and the impacts they may have on remote mountain summits? Because changes in vulnerable high mountain ecosystems may impact biodiversity and can have implications for species` responses to environmental changes (Markham *et al.* 1993; Grabherr *et al.* 1995; Thuiller *et al.* 2005; Fischlin *et al.* 2007; Engler *et al.* 2009). Of particular importance are long-term monitoring studies of high alpine ecosystems which can be used to assess impacts of environmental changes or even act as indicators of environmental concerns. This study investigates changes in plant species on mountain summits over the past century. Such studies can potentially help to steer mountain conservation management and can possibly help to predict future extinctions, colonizations and general changes in species communities.

This study is a resurvey of vascular plant species on 120 mountain summits in the Southeastern Swiss Alps. Historical plant surveys from 1871 to 1947 were compared with systematic plant resurveys of the same mountains from 2010 to 2011. Changes in the spatial distribution of vascular plant species on alpine summits were studied using two approaches: (1) changes in latitudinal and elevational ranges of species; (2) effects of spatial factors, including surface area and isolation, on species richness and species assemblages on alpine summits.

Species Range Shifts

Species range shifts were studied in order to understand the current and historic geographical patterns of species distribution and changes which may have occurred in

high alpine plant species patterns over the past century. A variety of range shifts metrics were quantified using GIS analysis.

The average range shifts in the alpine plant taxonomic group show noteworthy shifts over the past century in three ways: (1) range expansion, (2) north-northwestward latitudinal range shift, and (3) shifts to higher elevations. Average patterns of latitudinal alpine range shifts over the past century in our study area showed a species range expansion of 660.3 km^2 at an average rate of 66.7 km^2 per decade. On average, each species occurred on nine different mountain summits recently than historically. However, this change is more precisely explained by an average of five local extinctions (mountains which no longer have that species in recent data) and a mean of 14 local colonizations per species (mountains which historically did not have that species). Species have shifted an average of 8.77 km (0.86 km/decade) to the north-northwest (315.10°) in the alpine/nival habitat. Patterns of mean alpine altitudinal range shifts have shown significant changes as well. As revealed by the increase of maximum alpine elevation by 42.03 meters over the past century, alpine plants are indeed climbing in elevation. These findings are in agreement with other studies and predictive models of plant range shifts.

Effect of Spatial Abiotic Factors on Species Richness and Assemblages

In the second part of the study, I investigated which abiotic landscape and spatial factors may influence small-scale local patterns of species richness and assembly in the context of the island biogeography theory. Results show that species richness is not related to the surface area of the summit or isolation distances from other mountain peaks. Additionally, the similarity of species composition between mountains is not related to distance between peaks.

This study is presented in the larger context of the importance of long-term monitoring for conservation management and biodiversity concerns. Understanding changes in large scale and local scale patterns of species distribution can be used as a tool to continue high alpine ecosystem monitoring efforts in the future. Additionally, recognition of a species` individual or taxonomic responses to environmental changes may allow conservation managers to make informed decisions for the future of Swiss flora.

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